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COMPUTER PROGRAMS FOR HELICOPTER AERODYNAMIC STABILITY EVALUATION

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U.S. ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY
Aberdeen Proving Ground, Maryland

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The three equations of motion for helicopters are reviewed for both pitch and roll. These include provisions for a simplified second order stability augmentation system. Two methods of calculating the required stability derivatives and solution of the equations of motion in terms of period and time to damp or time histories for various control motions are shown.

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TABLE OF CONTENTS

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1. INTRODUCTION

The feasibility of new helicopter designs depends to a great extent upon an analysis of their flying qualities. Five programs have been developed to carry out feasibility analysis:

These programs evaluate:

1. Helicopter Stability Derivatives including static stability analysis
2. Solution of Longitudinal Equations of Motion
3. Longitudinal Motion (Time History)
4. Solution of Lateral Equation of Motion
5. Lateral Motion (Time History)

Provisions are included in the programs for investigation of stability augmentation.

A sample calculation is included for a utility helicopter. The helicopter used in the sample calculation was chosen to demonstrate the application of the mathematics only and the type of evaluation that can be made but not to evaluate present capability.

It is recognized that the helicopter chosen is not a current inventory item but was used because the dynamic components are representative of present design and there was extensive flight data available with and without the SAS to compare to calculated results.

In general, the procedures and notation follow those established for fixed wing aircraft. Calculation of the rotor stability derivatives are added and the familiar aircraft elevator, aileron, and rudder deflections δ_E, δ_A, and δ_R are replaced with the longitudinal cyclic,

lateral cyclic and tail rotor collective B_1, A_1, and Θ_{tR}. Differences in the rotor derivatives between articulated, rigid and teetering rotors may be evaluated with the stability derivative program.

2. GENERAL STABILITY PROBLEM

Normal aircraft have six equations of motion. The general solution of these equations is a breakdown of two sets of three into the longitudinal and lateral modes. Each of these are represented by a determinant, the solution of which is a quartic equation.

There are four possible solutions of the quartic according to the roots ,λ, being real or complex and having a positive or negative real part.

$$\lambda = a \pm b\, i \qquad \text{etc.}$$

A positive real part indicates an unstable or diverging motion and the complex root an oscillation. A measure of the damping of its oscillation is the time to damp to half or double amplitude.

$$T_{1/2} = \frac{.693}{a}$$

and period

$$p = \frac{2\pi}{b}$$

Another common way to write the stability quartic is to indicate the natural frequency, ω_n and damping ratio, ζ, as

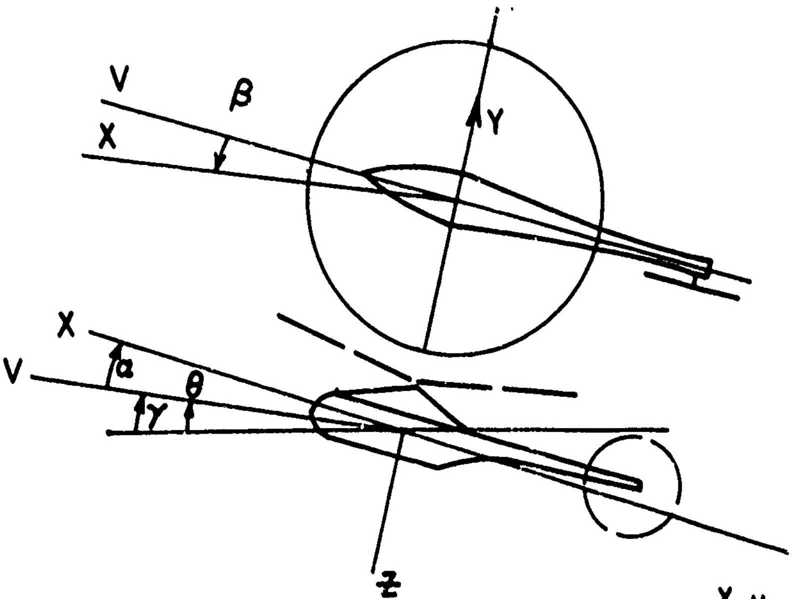
$$(s^2 + 2\zeta_1 \omega_{n_1} s + \omega_{n_1}^2)\ (s^2 + 2\zeta_2 \omega_{n_2} s + \omega_{n_2}^2)$$

The characteristic modes for nearly all aircraft in the longitudinal direction are two oscillations, one the long period or "phugoid" motion with very light damping and the other mode a short period one with

very heavy damping. In the lateral direction there are three normal modes. Two are aperiodic, one a very rapid convergence and the other a slow divergence known as "spiral divergence." The third mode is an oscillatory one, the well known "dutch roll."

In general, for stable oscillations, it is desirable to have damping ratios on the order of 0.6. Specifications for various types of aircraft generally give values of ζ, ω_n or P and $t_{\frac{1}{2}}$ that shall be contractually met, for example see MIL-H-8501A.

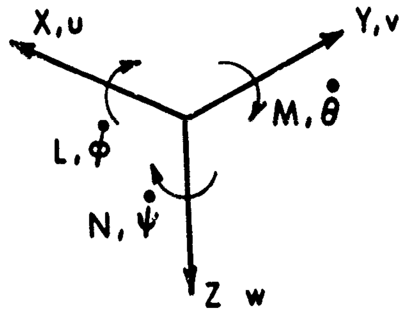
3. STABILITY EQUATIONS REVIEW



TOP VIEW

SIDE VIEW

FORCES	X	Y	Z
MOMENTS	M	L	N
ANGULAR VELOCTIES	$\dot{\theta}$	$\dot{\psi}$	$\dot{\phi}$
VELOCITIES	U	V	W



+ DIRECTIONS

$$\alpha = \frac{W}{V_s} \quad \beta = \frac{v}{V}$$

THE MOMENTS AND FORCES ACTING ON A VEHICLE ARE WRITTEN AS:

AIRPLANE	HELICOPTER	
$L = C_L \, 1/2 \, \rho V^2 S$	$= C_L \rho V_{TIP}^2 \pi R^2$	LIFT
$D = C_D \, 1/2 \, \rho V^2 S$	$= C_D \rho V_{TIP}^2 \pi R^2$	DRAG
$X = C_X \, 1/2 \, \rho V^2 S$	$= C_X \rho V_{TIP}^2 \pi R^2$	X AXIS FORCE
$Y = C_Y \, 1/2 \, \rho V^2 S$	$= C_Y \rho V_{TIP}^2 \pi R^2$	Y AXIS FORCE
$Z = C_Z \, 1/2 \, \rho V^2 S$	$= C_Z \rho V_{TIP}^2 \pi R^2$	7 AXIS FORCE
$L = C_L \, 1/2 \, \rho V^2 S b$	$= C_L \rho V_{TIP}^2 \pi R^3$	ROLLING MOMENT
$M = C_M \, 1/2 \, \rho V^2 S \bar{c}$	$= C_M \rho V_{TIP}^2 \pi R^3$	PITCHING MOMENT
$N = C_N \, 1/2 \, \rho V^2 S b$	$= C_N \rho V_{TIP}^2 \pi R^3$	YAWING MOMENT

The equations themselves are broken down into two parts, the left and right hand sides. The right hand side represents the inertia forces.

$$\Sigma F_x = m \dot{u} \qquad \Sigma F_y = m u (\dot{\beta} + \dot{\psi})$$

$$\Sigma F_z = m (\dot{w} - u \dot{\theta}) \qquad \Sigma L = I_x \ddot{\phi}$$

$$\Sigma M = I_y \ddot{\theta} \qquad \Sigma N = I_z \ddot{\psi}$$

The left hand forces and moments are series expanded in terms of the changes resulting from the perturbations in the linear and angular velocities and accelerations of the aircraft. These are known as the stability derivatives where

$$\Sigma F_y = \frac{\partial F_y}{\partial \beta} \beta + \frac{\partial F_y}{\partial \dot{\phi}} \dot{\phi} + \frac{\partial F_y}{\partial \dot{\psi}} \dot{\psi} + \qquad \text{etc.}$$

It is the purpose of this note to develop a program for estimating the stability derivatives of helicopters and additional programs to utilize these derivatives in solving the resulting equations of motion. A further objective is to develop step by step solutions so that a transient motion of the helicopter after a disturbance can be obtained.

Each of the forces varies with the disturbance velocities and their time derivatives:

$$X_u = \frac{\partial X}{\partial u} \qquad \dot{u} = \frac{\partial u}{\partial t}$$

$$X_{\dot{u}} = \frac{\partial X}{\partial \dot{u}} \qquad C X_u = \frac{\partial C_x}{\partial u} \qquad \text{etc}$$

The standard aircraft longitudinal equations in terms of the stability derivatives are:(for example see reference 11).

$$X_u u + X_\alpha \alpha \qquad - W\theta + X_{\delta_e}\delta_e = m\,\dot{u}$$

$$Z_u u + Z_\alpha \alpha + Z_{\dot{\alpha}}\dot{\alpha} \qquad Z_{\dot{\theta}}\dot{\theta} + Z_{\delta_e}\delta_e = m\,(\dot{w} - V\dot{\theta})$$

$$M_u u + M_\alpha \alpha + M_{\dot{\alpha}}\dot{\alpha} \qquad M_{\dot{\theta}}\dot{\theta} + M_{\delta_e}\delta_e = I_y\ddot{\theta}$$

$\delta_e = B_1$ = Pitch Cyclic Longitudinal Control Deflection

The lateral equations are:

$$Y_\beta \beta + Y_{\dot{\psi}}\dot{\psi} + W\phi + Y_{\dot{\phi}}\dot{\phi} + Y_{\delta_R}\delta_R + Y_{\delta_a}\delta_a = m\,(\dot{v} + V\dot{\psi})$$

$$L_\beta \beta + L_{\dot{\psi}}\dot{\psi} \qquad L_{\dot{\phi}}\dot{\phi} + L_{\delta_R}\delta_R + L_{\delta_a}\delta_a = I_x\ddot{\phi}$$

$$N_\beta \beta + N_{\dot{\psi}}\dot{\psi} \qquad N_{\dot{\phi}}\dot{\phi} + N_{\delta_R}\delta_R + N_{\delta_a}\delta_a = I_z\ddot{\psi}$$

$\delta_R = \theta_{tR}$ = Tail Rotor Collective Control Deflection

$\delta_A = A_1$ = Lateral Cyclic Control Deflection

$C_{y_\beta} = Y_\beta / q\pi R^2$ Typical Derivative Coefficient

Solution of these equations takes many forms.

For static lateral stability the variation of control deflection in steady sideslips based on solution of the determinants become:

$$\frac{d\phi}{d\beta} = \frac{-q\ \pi R^2}{W} \Big(C_{y_\beta} [C_{\ell_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{\ell_{A1}}]$$

$$- C_{\ell_\beta} [C_{y_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{y_{A1}}] + C_{n_\beta} [C_{y_{\theta TR}} C_{\ell_{A1}} - C_{\ell_{\theta TR}} C_{y_{A1}}]\Big)/$$

$$(C_{\ell_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{\ell_{A1}})$$

$$\frac{d\theta_{TR}}{d\phi} = - \frac{(C_{\ell_\beta} C_{n_{A1}} - C_{n_\beta} C_{\ell_{A1}})}{(C_{\ell_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{\ell_{A1}})} \frac{d\beta}{d\phi}$$

$$\frac{dA1}{d\phi} = - \frac{(C_{\ell_\beta} C_{n_{\theta TR}} + C_{n_\beta} C_{\ell_{\theta TR}})}{(C_{\ell_{\theta TR}} C_{n_{A1}} - C_{n_{\theta TR}} C_{\ell_{A1}})} \frac{d\beta}{d\phi}$$

$$C_{y_\beta} = Y_\beta / q\pi R^2 \qquad C_{\ell_\beta} = \frac{L_\beta}{q\pi R^3} \qquad \text{etc}$$

In a steady state turn $\beta = 0$ and the bank and turn rates become

$$\dot{\phi} = g \frac{\tan\phi}{V} \theta$$

$$\dot{\psi} = g \frac{\tan\phi}{V} \cos\phi$$

which leads to the result

$$\theta_{TR} = \frac{-g\,\frac{\tan\phi}{V}\,[\theta\,(C_{\ell_{A1}} C_{\ell_{\dot\phi}} - C_{n_{A1}} C_{n_{\dot\phi}}) - \cos\phi\,(C_{\ell_{A1}} C_{\ell_{\dot\psi}} - C_{n_{A1}} C_{n_{\dot\psi}})]}{C_{\ell_{\theta_{TR}}} C_{n_{A1c}} - C_{n_{\theta_{TR}}} C_{\ell_{A1c}}}$$

$$A1 = \frac{-g\,\frac{\tan\phi}{V}\,[\theta\,(-C_{\ell_{\theta_{TR}}} C_{n_{\dot\phi}} + C_{n_{\theta_{TR}}} C_{\ell_{\dot\phi}}) - \cos\phi\,(-C_{\ell_{\theta TR}} C_{n_{\dot\psi}} + C_{n_{\theta TR}} C_{\ell_{\dot\psi}})]}{C_{\ell_{\theta_{TR}}} C_{n_{A1}} - C_{n_{\theta_{TR}}} C_{\ell_{A1}}}$$

In pitch the variation of control gradient with speed is

$$\frac{dB_1}{du} = \frac{C_{z_u} C_{m_\alpha} - C_{m_u} C_{z_\alpha}}{-C_{z_{B1c}} C_{m_\alpha} + C_{m_{B1c}} C_{z_\alpha}}$$

The longitudinal cyclic pitch control required in a steady turn is

$$B_1 = \frac{g\,\frac{\tan\phi\,\sin\phi}{V}\,(C_{z_\alpha} C_{m_{\dot\theta}} - C_{m_\alpha} C_{z_{\dot\theta}}) + (\frac{1}{\cos\phi} - 1)\,C_{L_o} C_{m_\alpha}}{C_{z_\alpha} C_{m_{B_1}} - C_{m_\alpha} C_{z_{B_1}}}$$

or

$$B_1 = \frac{\frac{g}{V}\,(\frac{n^2 - 1}{n})(C_{z_\alpha} C_{m_{\dot\theta}} - C_{m_\alpha} C_{z_{\dot\theta}}) + (n - 1)\,C_{L_o} C_{n_\alpha}}{C_{z_\alpha} C_{m_{B_1}} - C_{m_\alpha} C_{z_{B_1}}}$$

$C_{L_o} = W/q\pi R^2$, n = Load Factor

For pitch trim in stabilized level flight the load factor, η, is 1. Moments about the C.G. as shown in Figure 1 give:

$$B_1 = \frac{\frac{X}{R} + \frac{H}{R}\frac{C_H}{C_T} + \frac{\mu^2}{2C_T}\frac{\lambda}{\mu}\left(2K_f V_f - C_{L_{\alpha_t}}\overline{TV}\right) - \left(2KV_f\ \alpha_{0L\beta} - C_{L_{\alpha_t}}\overline{TV}\ I_t\right)\frac{u^2}{2C_T}}{\frac{h}{R} - \frac{u^2}{2C_T}\left(2K_f V_f - C_{L_{\alpha_t}}\overline{TV}\right)}$$

For steady pull ups the pitch damping term, $Cm_{\dot{\theta}}$, may be added as indicated in figure 1.

Solution of the static stability equilibrium equations has been added to the stability determinant program, Appendix "A".

Dynamic stability analysis is considered in separate programs as discussed in the following section.

4. LONGITUDINAL ROOTS

The longitudinal determinant is

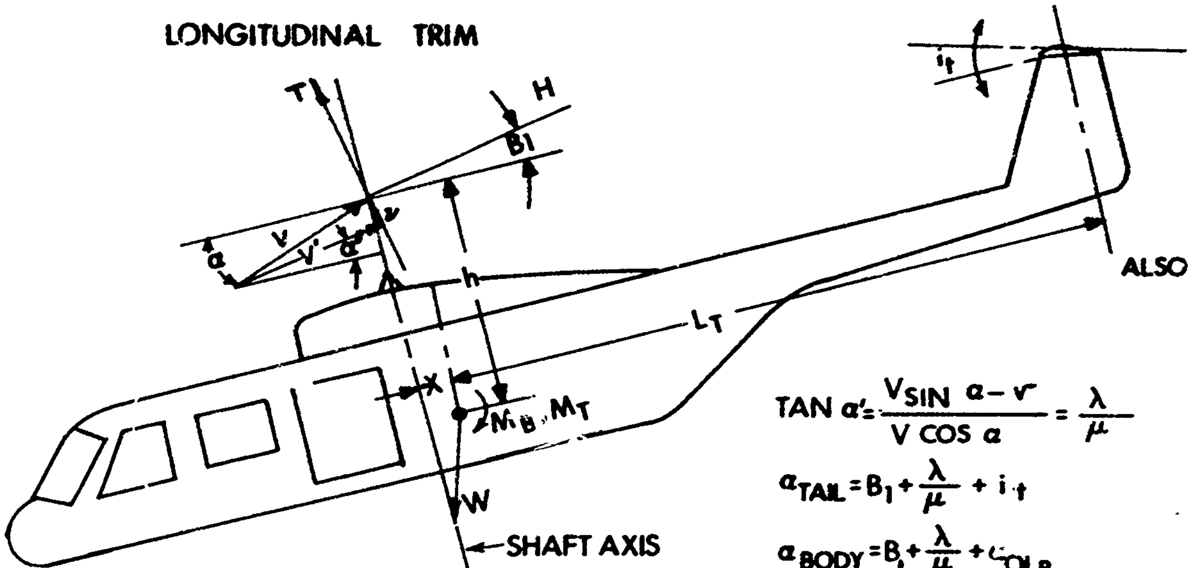
$$\begin{array}{ccc}
\underline{\mu} & \underline{\alpha} & \underline{\theta} \\
C_{x_\mu} - \frac{m'}{v}s & C_{x_\alpha} & -C_L \\
C_{Z_\mu} & C_{Z_\alpha} + (C_{Z_{\dot{\alpha}}} - m')s & (C_{Z_{\dot{\theta}}} + m')s \\
C_{m_\mu} & C_{m_\alpha} + C_{m_{\dot{\alpha}}}s & C_{m_{\dot{\theta}}}s - Iy's^2
\end{array}$$

where

$$m' = \frac{mv}{qA_b}, \quad I'y = Iyy/qA_D ROTR$$

FIGURE 1

LONGITUDINAL TRIM



$$\tan\alpha' = \frac{V_{\sin}\,\alpha - v}{V\cos\alpha} = \frac{\lambda}{\mu}$$

$$\alpha_{TAIL} = B_1 + \frac{\lambda}{\mu} + i_t$$

$$\alpha_{BODY} = B_1 + \frac{\lambda}{\mu} + \alpha_{OL_B}$$

$$\frac{\partial C_m}{\partial B_{1_{ROTOR}}} = \frac{\partial C_H}{\partial B_{1_{ROTOR}}} \quad \frac{h}{R} = -C_T\,\frac{h}{R}$$

$$\frac{2}{\mu^2} C_{m_{\alpha_B}} = 2K_f\overline{V_f} = \frac{2K_f VOLF}{\pi R^3}$$

$$\frac{2}{\mu^2}\,C_{m_{\alpha_t}} = -C_{L_{\alpha_t}} \times \frac{S_t\,\ell_t}{\pi R^3} = -\,C_{L_{\alpha_t}}\;\overline{TV}$$

$\cos B_1 = 1,\ \sin B_1 \approx 0$

$$\Sigma M_{CG} = Tx + H_h + M_{\alpha_B}\alpha_B + M_{\alpha_{TAIL}}\alpha_{t_{TAIL}} + M_{B1_{ROTOR}} B_1 + M_{\dot\theta}\;\frac{g(n-1)}{V}$$

$$= C_T\frac{X}{R} + C_h \cdot \frac{h}{R} + C_{m_{\alpha_B}}\,\alpha_B + C_{m_{\alpha_t}}\,\alpha_t + C_{m_{B_1}}\,B_1 + M_{\dot\theta}\;\frac{g(n-1)}{V}$$

$$B_1\frac{h}{R} = \frac{X}{R} + \frac{C_H}{C_T} \times \frac{h}{R} + \frac{\mu^2}{2C_T}\;2K_f\overline{V_f}\left(B_1 + \frac{\lambda}{\mu} - \alpha_{OB}\right) - \frac{\mu^2}{2C_T}C_{L_{\alpha_t}}\left(B_1 + \frac{\lambda}{\mu} + i_t\right) + \frac{C_{m\theta}}{CT}\;\frac{g(n-1)}{V}$$

$$B_1 = \frac{\frac{X}{R} + \frac{C_H}{C_T}\;\frac{h}{R} + \frac{\mu}{2CT}\;\frac{\lambda}{\mu}\left(2K_f\overline{V_f} - C_{L_{\alpha_t}}\;\overline{TV}\right) - \frac{\mu^2}{2CT}\left(2K_f V_f\;\alpha_{OL_B} - C_{L_{\alpha_t}}\overline{TV}i_t\right) + \frac{C_{m\dot\theta}}{C_T}\;\frac{g(n-1)}{V}}{\frac{h}{R} - \frac{\mu^2}{2C_T}\left(2K_f\overline{V_f} - C_{L_{\alpha_t}}\;\overline{TV}\right)}$$

This gives the stability quartic $A's^4 + B's^3 + C's^2 + D's + E'$.

Let $A = C_{x_\mu}$, $B = C_{z_\mu}$, $C = C_{x_\alpha}$, $E = C_{z_\alpha}$, $D = C_{z_{\dot\alpha}}\ m'$, $F = C_{z_{\dot\sigma}} + m'$

Then:

A'	B'	C'	D'	E'
$\frac{m'}{v} DIy'$	$-ADIy'$	$-AEIy'$	$AECm_{\dot\theta}$	$-BC_L C_{m_\alpha}$
	$\frac{m'}{v} EIy'$	$+ADCm_{\dot\theta}$	$-AFC_{m_\alpha}$	$EC_L C_{mu}$
	$\frac{-m'}{v} DC_{m_{\dot\theta}}$	$-AFCm_{\dot\alpha}$	$-BCC_{m\dot\theta}$	
	$+\frac{m'}{v} FC_{m_{\dot\alpha}}$	$-\frac{m'}{v} EC_{m_{\dot\theta}}$	$-BC_L C_{m_{\dot\alpha}}$	
		$+\frac{m'}{v} FC_{m_\alpha}$	CFC_{mu}	
		$+BCIy'$	$DC_L C_{mu}$	

These are solved in the program of Appendix "B". For hover the Z equation $V\dot\gamma$ term becomes $\dot\omega$. This is accomplished by setting v = 1 in the input of the program.

It is easy to introduce various autopilot gains into the quartic. For example, $C_{52} = B_1/\theta$ adds these terms to the quartic coefficients (Table B.1).

$\Delta C'$	$\Delta D'$	$\Delta E'$
$-\frac{m'}{v} DC_{52}Cm_{B1}$	$ADC_{52}\ Cm_{B1}$	$AEC_{52}Cm_{B1}$
$\frac{m'}{v} C_{52}Cm_{\dot\alpha}C_{Z_{B1}}$	$-AC_{52}Cm_{\dot\alpha}C_{Z_{B1}}$	$-AC_{52}Cm_{\alpha}C_{Z_{B1}}$
	$\frac{-m'}{v} EC_{52}Cm_{B1}$	$-BCC_{52}Cm_{B1}$

$\Delta C'$	$\Delta D'$	$\Delta E'$
—	$+\frac{m'}{V} C_{52}\, Cm_{\alpha} C_{Z_{B1}}$	$+CC_{mu} C_{52}\, C_{Z_{B1}}$
—	$-C_{Z_{\mu}}\, Cm_{\dot{\alpha}} C_{52} C_{x_{B1}}$	$-C_{Z_{\mu}}\, Cm_{\alpha} C_{52} C_{x_{B1}}$
—	$+Cm_{\mu} D\, C_{52} C_{x_{B1}}$	$+C_{m\mu} C_{Z_{\alpha}} C_{52} C_{x_{B1}}$

If for a given aircraft and flight condition a set of desired longitudinal phugoid - short period characteristics are required, a desired quartic is known:

$$
\begin{array}{rl}
A's^4 + B's^3 + C's^2 + D's + E' & \text{Desired} \\
A_1's^4 + B_1's^3 + C_1's^2 + D_1's + E' & \text{Aircraft Base} \\
\hline
\Delta A's^4 + \Delta B's^3 + \Delta C's^2 + \Delta D's + \Delta E' & \text{Increment}
\end{array}
$$

For each flight condition it is possible to solve for a set of feedback gains to satisfy this condition. Five sets would be required. For example with:

$$C'_{52} = B1/\theta \qquad C'_{15} = B1/\alpha$$

$$C'_{51} = B1/\dot{\theta} \qquad C'_{16} = B1/\dot{\alpha}$$

$$C'_{50} = B1/\ddot{\theta} \qquad C'_{17} = B1/\ddot{\alpha}$$

From the expansion of the stability quartic, obtain the coefficient increments due to each, see Table B.1.

$$A_{15} = \Delta A \text{ due to } C'_{15} \text{ etc.}$$

which gives for each flight condition the set:

$$A15\cdot C'15+A16\cdot C'16+A50\cdot C'50+A51\cdot C'51+A52\cdot C'52 = \Delta A_R$$

$$B15\cdot C'15+B16\cdot C'16+B50\cdot C'50+B51\cdot C'51+B52\cdot C'52 = \Delta B_R$$

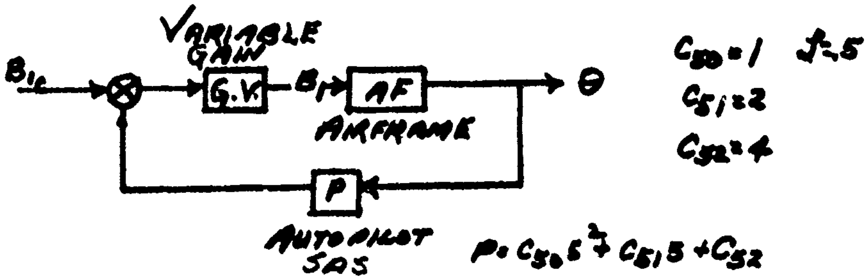
$$C15\cdot C'15+C16\cdot C'16+C50\cdot C'50+C51\cdot C'51+C52\cdot C'52 = \Delta C_R$$

$$D15\cdot C'15+D16\cdot C'16+D50\cdot C'50+D51\cdot C'51+D52\cdot C'52 = \Delta D_R$$

$$D15\cdot C'15+E16\cdot C'16+E50\cdot C'50+E51\cdot E'51+E52\cdot C'52 = \Delta E_R$$

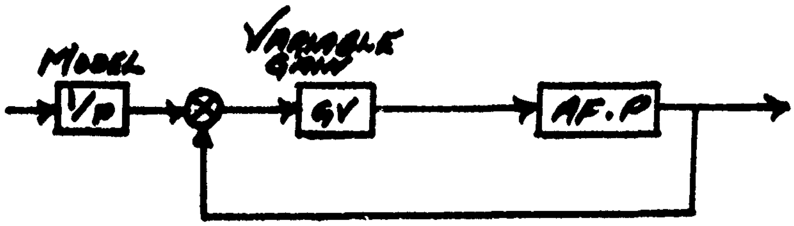
Solution of this set will give the desired stability.

Scheduling of 5 multiple gains through the entire flight regime becomes quite cumbersome. Usually, a hunt and trial method using only one or two gains to obtain an approximate solution is used. To avoid this problem the idea of the high gain-model following autopilot has been used.



In this figure, if the autopilot gains are adjusted so that a desired damping ratio of .5 or .6 is obtained, and if the variable gain is made large enough, the airframe dynamics will tend to be masked and the damping ratio set in to the autopilot will be obtained.

This arrangement is similar to the adaptive autopilot scheme (references 6, 10, and 12), except that the aircraft function is multiplied by the autopilot function in the equivalent circuit.



With this simplified arrangement an insight into the dynamic stability problem can be obtained by using the standard quartic root procedure as used for the airframe alone, see Table B.1. The required inputs have been set into Appendix B. A corresponding transient analysis is set up with provision for a variable gain in Appendix C.

Inspection of the $\ddot{\theta}$ equation shows in another way the influence of the autopilot terms

$$\ddot{\theta} = \frac{C_{m_\mu}\mu + C_{m_\alpha}\alpha + C_{m_{\dot{\alpha}}}\dot{\alpha} + GVC52C_{m_{B1}}\ddot{\theta} + (GVC51C_{m_{B1}} + C_{m_\theta})\dot{\theta}}{Iy' - GV * C50\ C_{m_{B1}}}$$

Thus it can be seen in the denominator an increase in GV or C50 is equivalent to a change in the moment of inertia.

5. Lateral Roots

The lateral determinant is

$$
\begin{array}{ccc}
\underline{\beta} & \underline{\psi} & \underline{\phi} \\
-m's + C_{Y_\beta} & (C_{Y_{\dot\psi}} - m')s & C_L + (C_{Y_{\dot\phi}} + m'\alpha)s \\
C_{\ell_\beta} & C_{\ell_{\dot\psi}} s & -I'_x s^2 + C_{\ell_{\dot\phi}} s \\
C_{n_\beta} & -I'_Z s^2 + C_{n_{\dot\psi}} s & +C_{n_{\dot\phi}} s
\end{array}
$$

where

$$m' = \frac{mV}{q\Pi R^2}, \quad I'_x = \frac{I_{xx}}{q\Pi R^3}, \quad I'_y = \frac{I_{YY}}{q\Pi R^3}$$

which gives the stability quartic $A's^4 + B's^3 + C's^2 + D's + E'$

A'	B'	C'	D'	E'
$m'I'_X I'_Z$	$-C_{Y_\beta} I'_Z I'_X$	$C_{Y_\beta} I_Z C_{\ell_{\dot\phi}}$	$-C_{\ell\beta} C_{Y\dot\psi} C_{n\dot\phi}$	$C_{\ell_\beta} C_{n_{\dot\psi}} C_L$
	$-m' I'_Z C_{\ell\dot\phi}$	$C_{Y_\beta} C_{n\dot\psi} I'_X$	$C_{\ell_\beta} m' C_{n\dot\phi}$	$-C_{n_\beta} C_{\ell_{\dot\psi}} C_L$
	$-m' I_X C_{n\dot\psi}$	$-m' C_{\ell\dot\psi} C_{n\dot\phi}$	$-C_{\ell\beta} I_Z C_L$	
		$m' C_{n\dot\psi} C_{\ell\dot\phi}$	$C_{\ell\beta} C_{n\dot\psi} C_{Y\dot\phi}$	
		$-C_{\ell\beta} I'_Z C_{Y\dot\phi}$	$C_{n\beta} C_{Y\dot\psi} C_{\ell_{\dot\phi}}$	
		$-C_{n\beta} I_X C_{Y\dot\psi}$	$-C_{n\beta} m' C_{\ell_{\dot\phi}}$	
		$C_{n\beta} m' I_X$	$-C_{n\beta} C_{\ell\dot\psi} C_{Y\dot\phi}$	
			$C_{Y\beta} C_{\ell\dot\psi} C_{n\dot\phi}$	
			$-C_{Y\beta} C_{n\dot\psi} C_{\ell\dot\phi}$	

These determinants are solved in the program of Appendix D. For hover, the side force equation term $V\ddot{\psi}$ disappears. This is accomplished by setting V=1 in the input of Appendix D. As for the longitudinal case, a simplified autopilot study is included. Autopilot gain coefficients are shown in Table D.1.

The corresponding transient analysis is included in the calculation of Appendix E.

6. STABILITY DERIVATIVES

Helicopter stability derivatives are influenced by the type of rotor. In general three types of rotor are commonly used.

1. articulated rotor
2. rigid rotor
3. teetering rotor

The first two transfer cyclic control moments directly to the rotor shaft. The cyclic lift couple for the first has an arm equal to the radius of the flapping hinge and the second equal to the radius of the blade spanwise center of lift. The teetering rotor develops its moment by tilting the lift vector about the C.G. No moment is developed at zero lift.

Two programs have been developed for estimating stability derivatives. The first program was based on combining the equations and data of reference 1 and 2. In general, this work was based on the articulated rotor only. In addition contributions of the rotor to some of the small damping turns were neglected.

For this reason a second program based on a rotor strip analysis was developed to calculate complete sets of stability derivatives including a complete model build up. The first program is shown in table A1 and the second table A2 of appendix A. The method of A1 being a closed solution is much cheaper to operate than program A2 which requires a great deal of machine iteration and thus machine time.

In general values obtained from these methods may be used where wind tunnel or other test data are not available. Some useage of

these methods and results obtained are presented in the following examples.

7. EXAMPLE CALCULATION

Several initial studies have been completed using the methods of this report. These are shown in appendix F.

The first study was completed using the abbreviated derivative calculation of table A1. The purpose of this study was to illustrate the influence of variations of the stability derivatives in the dynamic stability of a marginally stable basic helicopter examples I and II. In addition, the static stability relations of a utility helicopter was investigated in example III.

Stability derivatives are shown in Table F.1, Appendix F for typical study helicopters whose characteristics are:

			I	II	III
W	Weight	lbs.	11867	11867	14800
CDA	Helicopter drag area	sq. ft.	36.5	36.5	21
V	Velocity	ft/sec	100	0	169

			I	II	III
TIPMS	Main Rotor Tip Mach No.		.6	.6	.65
SIGMA	Main Rotor Solidity	B*C/ (3.14*R)	.062	.062	.09
ROTR	Main Rotor Radius	ft.	28	28	28
CI	Speed of Sound	ft/sec	1115	1115	1115
RHO	Density	slugs/ ft3	.0024	.0024	.0024
XR	Distance Rotor to CG Horiz.	ft-CG fwd	-.1	-.1	.5
HR	Distance Rotor to CG Vert.	ft+CG below	8.0	8.0	6.25
HF	Munks KF for Fuselages		.8	.8	.7
VOLF	Munks Fuselage Volume	cu. ft.	1000	1000	1500
ST	Area Horiz. Tail	sq. ft.	12.4	12.4	30
SVT	Area Vert. Tail	sq. ft.	20	20	25
LT	Tail Length	ft.	28	28	33.3
TI	Horiz. Tail Incidence	rad.	0	0	0
SIGMAT	Tail Rotor Solidity		.167	.167	.167
TRR	Tail Rotor Radius	ft.	4.7	4.7	5.0
DS	Angle Shaft to Body Axis (+δ AHD Z)	Rad.	.174	.174	.087
SG	1 for DP=RHO*VTIP*VTIP, 0 for DP=RHO*V*V/2		0	1	1.0
BMF	Blade Mass Factor = C*RHO*5.73 (ROTOR**2)/I		10	10	10
ETA	Load Factor		1.0	1.0	1.0

From the stability derivatives of Table F.1, dynamic flight characteristics have been calculated for examples I and II. These are shown in Appendix F, Tables F.2 through F.4. The effects of changes in stability derivatives and autopilot gains are shown. Figures F.1 to F.3 show typical motions of the aircraft with and without typical autopilot data.

Finally, static stability data are tabulated in Table F.4 for example III. The data include pitch, equilibrium sideslip trim and steady turn data. These data are also plotted in Figures F.4 to F.8.

Figure F.6 indicates that the utility helicopter of example III should have adequate longitudinal control for a CG range of 16.0 inches. This range could be extended to 27.0 inches by coupling the horizontal tail to the longitudinal cyclic control. However, this would be the maximum amount possible since the gradient of control position versus speeds becomes critical at the aft CG, see Figure F.5.

Some recent flight data is available on a series of Bell Hellicopters with stability augmentation off. These helicopters use a 44 foot diameter rotor with 27 inch chord operating at tip speed of 745 feet per second. Aircraft using this rotor include the UH-1C and AH-1 series. Tests of the AH-1 series found the airplane with stability augmentation off to be dynamically unstable although not uncontrollable for several flight conditions.

Stability derivatives were estimated for these aircraft at hover at 7100 lbs and level flight at 40 and 140 knots forward speed. All derivatives were estimated by the rotor strip analysis of table A-2. In addition for the hover condition derivatives were estimated by the method of both tables A1 and A2. These are tabulated in Table F.6. The estimated differences between using an equivalent teetering, articulated or rigid rotor at hover are also shown in Table F.6.

Calculated values of the period, P, and time to damp, t, using these derivatives are compared with flight values as follows:

where P/t   +t time to double

        -t time to half

LONGITUDINAL (NO SAS)

	Calculated	Flight	AH-1 ( ) Model
Hover	16/Divergent		
40 kts	5.5/+63	16/+4	(R)
		5/Neutral	(Q)
140 kts	DEAD BEAT	DEAD BEAT	(Q)

LATERAL (NO SAS)

Hover	5./Divergent		
40 kts	Divergent	Divergent	(R)
		5./-5	(Q)
140 kts	2.8/100	4.5/Neutral	(Q)

In summary the methods of computing stability derivatives shown in table A-1 and A-2 both need continual correlation and updating. The methods may be used as a basis of correlation or for use in preliminary estimates where wind tunnels or other test data is not available.

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APPENDIX A

HELICOPTER STABILITY DERIVATIVE PROGRAM

TABLE A-1

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                    CLOSED SOLUTION ANALYSIS
                 HELICOPTER STABILITY DERIVATIVES
C                 UTILIZATION PROGRESS REPORT

C
C        THIS PROGRAM EVALUATES STABILITY DERIVATIVES FOR A SINGLE ROTOR
C     HELICOPTER.   THIS FIRST CUT PROGRAM IS LARGELY BASED ON METHODS
C     OUTLINED IN SECKELS BOOK COMBINED WITH DATA FROM SIKORSKY AND
C     BOEING ROTOR CHARTS.
C        THE REQUIRED INPUT CARDS AND PROPER COLUMNS ALONG WITH THE SYMBOLS
C     AND IDENTIFICATION ARE PRESENTED IN THE FOLLOWING TABLE.
C
C    CARD  COLUMN SYMBOL
C     1     1-10  W        WEIGHT                              LBS
C     1    11-20  CDA      HELICOPTER DRAG AREA                SQ. FT.
C     1    21-30  V        VELOCITY                            FT/SEC
C     1    31-40  TIPMS    MAIN ROTOR TIP MACH NO
C     1    41-50  SIGMA    MAIN ROTOR SOLIDITY                 B*C/(3.14*R)
C     1    51-60  ROTR     MAIN ROTOR RADIUS                   FT.
C     1    61-70  C1       SPEED OF SOUND                      FT./SEC.
C     2     1-10  RHO      DENSITY                             SLUGS/FT3
C     2    11-20  XR       DISTANCE ROTOR TO C.G. HORIZ        FT -C.G. FWD
C     2    21-30  HR       DISTANCE ROTOR TO C.G. VERT.        FT +C.G. BELOW
C     2    31-40  HF       MUNKS KF FOR FUSELAGES
C     2    41-50  VOLF     MUNKS FUSELAGE VOLUME               CU.FT.
C     2    51-60  ST       AREA HORIZ TAIL                     SQ.FT.
C     2    61-70  SVT      AREA VERT  TAIL                     SQ.FT.
C     3     1-10  LT       TAIL LENGTH                         FT.
C     3    11-20  TI       HORIZ TAIL INCIDENCE                RAD.
C     3    21-30  SIGMA   TAIL ROTOR SOLIDITY
C     3    31-40  TRR      TAIL ROTOR RADIUS                   FT.
C     3    41-50  DS       ANGLE SHAFT TO BODY AXIS +S AHD Z RAD
C     4    1-10   SG       1 FOR DP =RHO*VTIP*VTIP  0 FOR DP=RHO*V*V/2
C     4   11-20   BMF     BLADE MASS FACTOR=C*RHO*5.73*(ROTOR**4)/I
C     4   21-30   ETA     LOAD FACTOR
C     4   31-40  BTI      RATIO DBI/DTI PITCH CYCLIC TO TAIL INCIDENCE
C
C                   TYPICAL INPUT DATA ARE
C11867.    36.5      100.      .6        .0622     28.       1115.
C.0024     -1.       8.        .8        1000.     12.4      20.
C28.       0.        .167      4.67      .174
C1.        10.       1.        0.
C
      CALL TANNRH(TIPMS,SIGMA,CTOSH,CQOSH,CTSTH,0)
      CALL TANNES(TIPMS,OMUHS,CLOS,CDOSS,CQOSS,CQDOSS,0,ACSS)
   77 READ(5,1)W,CDA,V,TIPMS,SIGMA,ROTR,C1
      READ(5,1)RHO,XR,HR,HF,VOLF,ST,SVT
      READ(5,1)TL,TI,SIGMAR,TRR,DS
C        TO CALCULATE LONGITUDINAL CYCLIC, B1C, IN PULL UP SET ETA
C     (LOAD FACTOR) IN CARD 4.   NORMALLY ETA =1.   FOR HOVER ETA =1.
      READ(5,1)SG,BMF,ETA,BTI
      WRITE(6,71)
```

```
      WRITE(6,2)
    2 FORMAT(10X,10HINPUT DATA)
      WRITE(6,1)W,CDA,V,TIPMS,SIGMA,ROTR,C1
      WRITE(6,1)RHO,XR,HR,HF,VOLF,ST,SVT
      WRITE(6,1)TL,TI,SIGMAR,TRR,DS
      WRITE(6,1)SG,BMF,ETA,BTI
      IF(ETA-1.)13,13,12
   12 ETB=32.2*(ETA-1.)/V
      GOTO14
   13 ETB=0.
   14 CONTINUE
   51 FORMAT(1H1)
      VTIP=TIPMS*C1
      DP=RHO*V*V/2.
      OMUHS=V/VTIP
      AS4=SIGMA*5.73/4.
      AD=3.141*ROTR*ROTR
      CT=W/(AD*VTIP*VTIP*RHO)
      ELO=-1./((2./CT)**.5)
      CLOS=CT/SIGMA
      CTAS=2.*CT/(5.73*SIGMA)
      CDOS=(CDA*DP)*CTAS/W
      IF(OMUHS)60,61,60
   60 CALL TANNES(TIPMS,OMUHS,CLOS,CDOS,CQOS,CQDOS,1,ACS2)
      GOTO 62
   61 CALL TANNRH(TIPMH,SIGMA,CLOS ,CQOS ,CTSTH,1)
      DP=RHO*VTIP*VTIP
      DP1=DP
      WRITE(6,95)
   62 CONTINUE
C     XU=(DX/DU)/M =(G/CT)*(BR)  SECKEL SYSTEM
C     CXU NATURAL AIRCRAFT SYSTEM=(M/Q*AD)*XU   ALPHA=W/V
C     CXU NATURAL HELICOPTER SYSTEM = USE QH=RHO*VTIP*VTIP  V=1. THEN AL=W
C     THEREFORE SET SG=1 FOR HELICOPTER SYSTEM, SG=0 FOR AIRCRAFT SYSTEM
C     NOTE COR  CT PM IN DYNAMIC PROGRAMS TO MATCH
      IF(SG)91,91,90
   90 DP=RHO*VTIP*VTIP
      WRITE(6,93)
      GOTO92
   91 WRITE(6,94)
   92 CONTINUE
      DPF=RHO*V*V/(2.*DP)
      CQAS=2.*CQOS/5.73
      Q1=(4.2+38.*CTAS+2.*OMUHS)/10000.
      Q3=(-1.8-2.86*OMUHS**2.5)/10000.
      Q2=(CQAS-Q1)/(CTAS**2)
      ELS=-3.* MUHS-(.92-.5*OMUHS)*Q2
      Q2=Q2+Q3*ELS/CTAS
      ELW=ELS*CTAS
      TSRP=OMUHS*(2./CT)**.5
      IF(TSRP-1.)20,20,21
   20 DLDW=.5+.25*TSRP
      DLDCT=(.25+.03*TSRP)/ELO
      DLDU=.35*TSRP
      EL1=.4*TSRP
      GOTO 28
   21 IF(TSRP-2.)22,22,23
   22 DLDW=.75+.2*(TSRP-1.)
      DLDCT=(.28-(.06*(TSRP-1.)))/ELO
      DLDU=.35-(.14*(TSRP-1.))
```

```
      EL1=.4-(.08*(TSRP-1.))
      GOTO 28
   23 IF(TSRP-3.)24,24,25
   24 DLDW=.95+(.25*(TSRP-2.))
      DLDCT=(.22-(.04*(TSRP-2.)))/ELO
      DLDU=.21-(.1*(TSRP-2.))
      EL1=.32-(.04*(TSRP-2.))
      GOTO 28
   25 IF(TSRP-6.)26,26,27
   26 DLDW=1.
      DLDCT=(.18-(.0333*(TSRP-3.)))/ELO
      DLDU=.11-(.0333*(TSRP-3.))
      EL1=.28-(.04*(TSRP-3.))
      GOTO 28
   27 DLDW=1.
      DLDCT=.08/ELO
      DLDU=.01
      EL1=.16
   28 DLDU=DLDU+.005*ABS2
      DCTDT=(1.+1.5*OMUHS*OMUHS)/(3.*(1.-AS4*DLDCT))
      DCTDW=.5*DLDW/(1.-AS4*DLDCT)
      DCTDU=(3.*OMUHS/(1.+1.5*OMUHS*OMUHS))*(CTAS-ELW/2.)
      DCTDU=(DCTDU+.5*DLDU)/(1.-AS4*DLDCT)
      R=ROTR
   31 UP=((XR/R)+(OMUHS*2.*ELS*(HF*VOLF-1.43*TL*ST)/(5.73*SIGMA*AD*ROTR)
     1-OMUHS*OMUHS*(HF*VOLF*0.+1.43*TL*ST*TI)/(CT*AD*ROTR)))
      DN=(HR/R)-OMUHS*OMUHS*(HF*VOLF-1.43*(BTI+1.)*ST*TL)/(CT*AD*ROTR)
      H4=(6.95*OMUHS**.92)-1.1*OMUHS*ELS
      UP=UP+(.0125*OMUHS/(11.4*CTAS)+H4*CTAS-16.*ETB*R*(1.+ELS/4.)/(BMF*
     1VTIP))*HR/R
      B1C=UP/DN
      T1C=(CTAS-ELW/2.)*3.*57.3/(1.+1.5*OMUHS*OMUHS)
      H4P=1.+(10.*(1.-OMUHS)**2.95)*ELS
      H1P=15.7*OMUHS-.685*ELS*OMUHS**.605
      H2P=-.9*OMUHS+.003*ELS
      H3P=8.-5.*OMUHS-(1.5-2.25*OMUHS)*ELS
      H5P=1.0+3.1*OMUHS**2.04+(.25-.07*OMUHS)*ELS
      DCHDT=(-B1C+CTAS*(H1P+2.*AS4*H2P*DLDCT))*DCTDT
      DCHDW=(-B1C+CTAS*(H1P+2.*H2P))*DCTDW
      DCHDU=(-B1C+CTAS*(H1P*2.*AS4*H2P*DLDCT))*DCTU+H2P*CTAS*DLDU+H3P*CT
     1AS*CTAS+.0125/11.46
      DCHDQ=-16.*CTAS*H5P/BMF
      DCHDB1=- MUHS*DCHDW-CTAS
      DCTDB1=-DCTDW*OMUHS
      DCTDP=(OMUHS/4.)/(1.-AS4*DLDCT)
      AS5=AS4*SIGMAR/SIGMA
      CO1=W/(VTIP*CTAS*DP*AD)
      CXUR=CO1*(-DCHDU+DS*(DCHDW+DCTDU)-DS*DS*DCTDW)
      CXU=CXUR-2.*RHO*V*CDA/(DP*AD)
      CXW=CO1*(-DCHDW+DS*DCTDW)
      CXA=CXW*V
      CO2=W/(CTAS*DP*AD)
      CXTC=CO2*(DCTDT*DS-DCHDT)
      CXB1=CO2*(DCTDB1*DS-DCHDB1)
      CZU=CO1*(DCTDU-DS*DCTDW)
      CZW=-CO1*DCTDW
      CZA=CZW*V
      CZTC=-CO2*DCTDT
      CZB1=-CO2*DCTDB1
      CO3=CO1/RCTR
```

```
      CMUR=C03*(XR*(DCTDU-DS*DCTDW)+HR*(DCHDU-DS*DCHDW))
      IF(V)70,70,71
   70 C04=0.
      C05=0.
      CYBB=-.005*(VOLF**.67)/AD
      ENVF=0.
      C20=0.
      CMUF=0.
      CMUT=0.
      GOTO 73
   71 C04=HF*VOLF*RHO*V/(DP*AD*ROTR)
      ENVF=-C01*HF*VOLF*2.*OMUHS/(AD*5.73*SIGMA*2.*ROTOR)
      CYBB=((-.20*CDA/(AD*.6))-2.86*SVT*RHO*V*V/(2.*DP*AD))
      CYVB=CYBB/V
      C05=-ST*TL*2.86*RHO*V/(DP*AD*ROTR)
      C20=-2.86*SVT*V*V/(2.*VTIP*VTIP*AD)
      CMUF=C04*((ELW/OMUHS)+2.*(B1C-0.0+DCTDU-3.*OMUHS*(CTAS-ELW/2.)))
      CMUT=C05*((ELW/OMUHS)+2.*(B1C+TI+DCTDU-3.*OMUHS*(CTAS-ELW/2.)))
   73 CONTINUE
C     CMU FOR V GT 20.
      CMU=CMUR+CMUF+CMUT
      C06=-W*2.86*ST*TL*TL/(VTIP*VTIP*CTAS*5.73*SIGMA*AD*DP*AD*ROTR)
      CMWD=C06*(1.-2.*DCTDW)
      CMWR=C03*(XR*DCTDW+HR*DCHDW)
      CMWT=C03*((OMUHS/(AS4*AD))*(VOLF*HF-(4.30*ST*TL/2.)))*DCTDW
      CMW=CMWR+CMWT
      CMAD=C06*V*(1.-2.*DCTDW)
      CMAR=C03*V*(XR*DCTDW+HR*DCHDW)
      CMAT=C03*V*((OMUHS/(AS4*AD))*(VOLF*HF-(4.30*ST*TL/2.)))*DCTDW
      CMA=CMAR+CMAT
      CMTD=-C03*TL*2.86*OMUHS*ST*TL*DPF/(2.*AS4*AD)+C01*DCHDQ*HR/ROTR
      CMIT=-ST*TL*2.86/(AD*ROTR)
      CMIT=CMIT*RHO*V*V/(2.*DP)
      C06=W/(CTAS*DP*AD*ROTR)
      CMTC=C06*(DCTDT*XR+HR*DCHDT)
      CMB1=C06*(XR+DCTDB1+HR*DCHDB1)
C     END LONGITUDINAL DERIVATIVES START LATERAL
      Y01=1.55*OMUHS**.81
      Y0P=Y01-(10.+ELS)*(Y01+.82*OMUHS**1.82)/12.
      Y02=-1.5+2.*OMUHS
      Y0DP=Y02-(10.+ELS)*(Y02-1.5-.05*OMUHS)/12.
      Y02=.90*OMUHS**.68
      Y1P=Y02-(10.+ELS)*(Y02+(1.85*OMUHS**2.7))/12.
      Y2P=-.238*OMUHS-(10.+ELS)+(.108*OMUHS)/12.
      Y02=-1.5+.5*OMUHS
      Y3P=Y02-(10.+ELS)*(Y02-1.+3.38*OMUHS**1.93)/12.
      Y02=22.5-13.*OMUHS
      Y4P=Y02-(10.+ELS)*(Y02-5.)/12.
      A1C=B1C
      DCYDT=DCTDT*(A1C+EL1*(1.+AS4*DLDCT/2.))
      DCYDV=-.0125/11.46-Y4P*CTAS*CTAS-DCTDW*A1C*(A1C+1.5*EL1)
      DCYDT=DCYDT+DCTDT*BMF*CTAS*Y0P*(Y1P+2.*AS4*Y2P*DLDCT)
      DCYDP=.0625*OMUHS*EL1+DCTDP*(A1C+EL1*(1.+AS4*DLDCT/2.))
      DCYDP=DCYDP-16.*CTAS*Y3P/BMF+DCTDP*BMF*(Y1P+2.*AS4*Y2P*DCLDT)*CTAS
      DCYDV=DCYDV-DCTDW*A1C*BMF*CTAS*(Y1P+2.*Y2P)
      CYVR=C01*DCYDV
      CTWTR=.25/(1.-AS5*.25)
      CYVTR=C01*CTWTR*SIGMAR*TRR*TRR/(SIGMA*ROTR*ROTR)
      CYVTR=-CYVTR
      CYB=V*(CYVR+CYVTR)+CYBB
```

```
      CYA1C=W/(DP*AD)
      CLB=C03*V*HR*DCYDV
      CLTD=C01*HR*DCYDP
      CLA1=W*HR/(DP*AD*ROTR)
      ENVTR=C03*TL*CTWTR*SIGMAR*TRR*TRR/(SIGMA*ROTR*ROTR)
      ENVT=ENVF*1.43*SVT*TL/(-HF*VOLF)
      ENVR=C03*DS*HR*DCYDV
      CNB=V*(ENVF+ENVT+ENVTR+ENVR)
      ENRTR=-TL*ENVTR
      ENRT=-TL*ENVT
      ENRRR=ROTR*DS*DS*HR*DCYDP*C03
      CNSD=ENRT+ENRTR+ENRRR
      CNTD=ENRRR/DS
      CNA1=CLA1*DS
      CTTTR=1./(3.*(1.-AS5*.25))
      CNTTR=-W*TRR*TRR*TL*CTTTR/(CTAS*ROTR*ROTR*DP*AD*ROTR)
1     FORMAT(7F10.4)
      CYV=(CYVR+CYVTR)+CYVB
      CLV=C03*HR*DCYDV
      CNV=ENVF+ENVT+ENVTR+ENVR
      CYSD=-CYVTR*TL+C20
      WRITE(6,3)
    3 FORMAT(10X,11HOUTPUT DATA)
      CLSD=0.
      CYTD=0.
      WRITE(6,4)
    4 FORMAT(10X,71HLONGITUDINAL DERIVATIVES ARE IN ORDER CXU,CXA,CZU,CZ
     1A,CMU,CMA,CMAD,CMTD)
      WRITE(6,5)CXU,CXA,CZU,CZA,CMU,CMA,CMAD,CMTD
    5 FORMAT(9E14.7)
      WRITE(6,6)CZB1,CMB1,CXB1
    6 FORMAT(10X,19HCYCLIC CONTROLCZB1=,E15.8,1X,5HCMB1=,E15.8,1X,5HCXB1
     1=,E15.8)
      WRITE(6,7)CZTC,CMTC,CXTC
    7 FORMAT(10X,23HCOLLECTIVE CONTROLCZTC=,E15.8,1X,5HCMTC=,E15.8,1X,5H
     1CXTC=,E15.8)
      WRITE(6,8)CMIT
    8 FORMAT(10X,25HHORIZ. TAIL CONTROL CMIT=,E15.8)
      WRITE(6,9)
    9 FORMAT(10X,84HLATERAL STABILITY DERIVATIVES IN ORDER ARE CYB,CLB,C
     1NB,CYSD,CLSD,CNSD,CYTD,CLTD,CNTD)
      WRITE(6,5)CYB,CLB,CNB,CYSD,CLSD,CNSD,CYTD,CLTD,CNTD
      WRITE(6,10)CYA1C,CLA1,CNA1
   10 FORMAT(10X,20HCYCLIC CONTROL CYA1=,F15.8,1X,5HCLA1=,E15.8,1X,5HCNA
     11=,E15.8)
      WRITE(6,11)CNTTR
   11 FORMAT(10X,28HTAIL ROTOR COLLECTIVE CNTTR=,E15.8)
      WRITE(6,80)
      WRITE(6,5)DLDU,DLDW,DLDCT,DCTDT,DCTDW,DCTDU,DCTDB1,DCTDP
      WRITE(6,81)
      WRITE(6,5)DCHDT,DCHDW,DCHDU,DCHDB1
      WRITE(6,82)
      B1C=B1C*57.3
      WRITE(6,5)B1C,CTAS,CT,ELO,EL1,ELS,CQOS,T1C
   80 FORMAT(1X,68HAUXILIARY DERIVATIVES DLDU,DLDW,DLDCT,DCTDT,DCTDW,DCT
     1DU,DCTDB1,DCTDP)
   81 FORMAT(1X,25H DCHDT,DCHDW,DCHDU,DCHDB1)
   82 FORMAT(1X,33H B1C,CTAS,CT,ELO,EL1,ELS,CQOS,T1C)
      WRITE(6,96)
      WRITE(6,5)CXW,CZW,CMW,CMWD,CYV,CLV,CNV
```

```
   96 FORMAT(10X,64HTHE VELOCITY DERIVATES ARE IN ORDER CXW,CZW,CMW,CMWD
     1,CYV,CLV,CNV)
   93 FORMAT(20X,18H HELICOPTER SYSTEM)
   94 FORMAT(20X,16H AIRCRAFT SYSTEM)
   95 FORMAT(25X,5HHOVER)
   50 FORMAT(1HC)
      WRITE(6,5)CMUR,CMAR,CMWR,CZW,CZA
      WRITE(6,50)
      IF(V)19,15,19
   19 CONTINUE
      CLTTR=0.
      CYTTR=-R*CNTTR/TL
C     STATIC STABILITY
C     STEADY SIDESLIPS
      DTDB=-(DP*AD/W)*(CYB*(CLTTR*CNA1-CNTTR*CLA1)-CLB*(CYTTR*CNA1-CNTTR
     1*CYA1C)+CNB*(CYTTR*CLA1-CLTTR*CYA1C))
      DTRDT=-(CLB*CNA1-CNB*CLA1)/DTDB
      DAIDT=-(CLB*CNTTR+CNB*CLTTR)/DTDB
      DN2=CLTTR*CNA1-CNTTR*CLA1
      DTDB=DTDB/DN2
      WRITE(6,18)DTDB,DTRDT,DAIDT
C     STEADY TURN
      PHI=0.
      DPHI=10./57.3
      DO 15 K=1,5
      PHI=PHI+DPHI
      SN=32.2*SIN(PHI)/(COS(PHI)*V)
      THT=-30./57.3
      DTHT=15./57.3
      DO 15 KK=1,3
      THT=THT+DTHT
      TTR=-SN*(THT*(CLA1*CLTD-CNA1*CNTD)-COS(PHI)*(CLA1*CLSD-CNA1*CNSD))
      TTR=TTR/DN2
      A1=-SN*(THT*(-CLTTR*CNTD+CNTTR*CLTD)-COS(PHI)*(CLTTR*CNSD+CNTTR*CL
     1SD))/DN2
      PF=1./COS(PHI)
      B1=SN*SIN(PHI)+(((1./COS(PHI))-1.)*CMA*W/(DP*AD))/(CZA*CMTD-CMA*CZ
     1TD)
      THP=THT*57.3
   16 FORMAT(1X,12H STEADY TURN,12H BANK ANGLE=,F5.0,13H CLIMB ANGLE=,F5
     1.0,13H LOAD FACTOR=,F6.2)
      PHP=PHI*57.3
      WRITE(6,16)PHP,THP,PF
      TTRP=57.3*TTR
      A1P=A1*57.3
      B1P=B1*57.3
      WRITE(6,17)TTRP,A1P,B1P
   17 FORMAT(1X,38H CONTROL ANGLES TAIL ROTOR COLLECTIVE=,F6.2,16H LATER
     1AL CYCLIC=,F6.2,14H PITCH CYCLIC=,F6.2)
   18 FORMAT(1X,33H STEADY SIDESLIP RATIOS PHI/BETA=,F9.5,27H TAIL ROTOR
     1 COLLECTIVE/PHI=,F9.5,20H LATERAL CYCLIC/PHI=,F9.5)
   15 CONTINUE
      GOTO77
      END
      SUBROUTINE TANNRH(TIPMH,SIGMA,CTOSH,CQOSH,CTSTH,IREAD)
      DIMENSION SIG(7),CTH(9,5,3),CQH(9,5,3),CQX(3),CQXX(3)
      EQUIVALENCE(IN,INPUT)
  150 FORMAT(13F6.4)
      IN=5
      MADLY=6
```

```
      IF(IREAD)153,153,154
  153 READ(INPUT,150)(((CTH(K,J,I),K=1,9),J=1,5),I=1,3)
      READ(INPUT,150)(((CQH(K,J,I),K=1,9),J=1,5),I=1,3)
      SIG(1)=.05
      DO 151 I=2,6
  151 SIG(I)=SIG(I-1)+.025
  149 FORMAT(1H ,38HTANNER DATA FOR HOVER HAS BEEN READ IN)
      WRITE(MADLY,149)
      GO TO 50
  154 DO 155 J=1,4
      IF(SIG(J)-SIGMA)155,156,156
  155 CONTINUE
  156 CALL ZINDEX(J,JA,JB,JC)
      DO 157 K=1,8
      IF(CTH(K,1,1)-CTOSH)157,158,158
  157 CONTINUE
  158 CALL ZINDEX(K,KA,KB,KC)
      DO 160 I=1,3
      DO 159 J=JC,JA
      CALL CURVEB(CTH(KA,J,I),CTH(KB,J,I),CTH(KC,J,I),CQH(KA,J,I),
     1CQH(KB,J,I),CQH(KC,J,I),CTOSH,CQX(J))
  159 CONTINUE
      CALL CURVEB(SIG(JC),SIG(JB),SIG(JA),CQX(JC),CQX(JB),CQX(JA),SIGMA,
     1CQXX(I))
  160 CONTINUE
      CALL CURVEB(0.5,0.6,0.7,CQXX(1),CQXX(2),CQXX(3),TIPMH,CQOSH)
      CALL CURVEB(SIG(JC),SIG(JB),SIG(JA),CTH(9,JC,1),CTH(9,JB,1),
     1CTH(9,JA,1),SIGMA,CTHX)
      CALL CURVEB(SIG(JC),SIG(JB),SIG(JA),CTH(8,JC,2),CTH(8,JB,2),
     1CTH(8,JA,2),SIGMA,CTHY)
      CALL CURVEB(SIG(JC),SIG(JB),SIG(JA),CTH(7,JC,3),CTH(7,JB,3),
     1CTH(7,JA,3),SIGMA,CTHZ)
      CALL CURVEB(0.5,0.6,0.7,CTHX,CTHY,CTHZ,TIPMH,CTSTH)
      CQOSH=1.1*CQOSH
   50 RETURN
      END
      SUBROUTINE CURVEB(X1,X2,X3,Y1,Y2,Y3,X,Y)
      IF(X1-X2)111,110,111
  110 X1=X1+.0001
      WRITE(6,120)X1,X2,X3,Y1,Y2,Y3
  111 IF(X1-X3)113,112,113
  112 X1=X1+.0001
      WRITE(6,120)X1,X2,X3,Y1,Y2,Y3
  113 IF(X2-X3)115,114,115
  114 X2=X2+.0001
      WRITE(6,120)X1,X2,X3,Y1,Y2,Y3
  115 CONTINUE
  120 FORMAT(6E15.8)
      B1=Y1/((X1-X2)*(X1-X3))
      B2=Y2/((X2-X1)*(X2-X3))
      B3=Y3/((X3-X1)*(X3-X2))
      A1=(B1*X2*X3)+(B2*X1*X3)+(B3*X1*X2)
      A2=-B1*(X2+X3)-B2*(X1+X3)-B3*(X1+X2)
      A3=B1+B2+B3
      Y=A1+(A2*X)+(A3*(X**2))
      RETURN
      END
      SUBROUTINE CURVEC(X1,X2,X3,Y1,Y2,Y3,X,Y)
      ZD=((Y2-Y1)/(X1-X2))-((Y3-Y1)/(X1-X3))
      IF(ABS(ZD)-.0000001)1,2,2
```

```
    1 ZD=.00000001
    2 ZA=((((Y1*X1)-(Y3*X3))/(X1-X3))-(((Y1*X1)-(Y2*X2))/(X1-X2)))/ZD
      ZC=((Y1*X1)-(Y1*ZA)-(Y3*X3)+(Y3*ZA))/(X1-X3)
      Y=ZC+(((X1-ZA)*(Y1-ZC))/(X-ZA))
      RETURN
      END
      SUBROUTINE ZINDEX(IT,ITA,ITB,ITC)
      ITA=IT
      ITB=IT-1
      ITC=IT-2
      IF(ITC)1,1,2
    1 ITA=3
      ITB=2
      ITC=1
    2 CONTINUE
      RETURN
      END
      SUBROUTINE TANNES(TIPM,OMU,CL,CD,CQ,CDM7,IREAD,AC)
      DIMENSION CDS(4,6,25),CQS(4,6,25),EAC(4,6,25),J1(4),PU(4)
      DIMENSION CLA(4,6,5),CDM(4,6,5),K1(5),CD7(5),CQ7(5),EA7(5),PCC(5)
C     BOE ROTOR PERF. CHARTS STRAIGHT LINE INTERPOLATION VALUES OF MT/MU
C     MT=.68/.2,.5,.8,1.,1.2,1.5    MT=.95/.31,.47,.66
C     MT=.77/.33,.52,.79,1.06    MT=.875/.35,.52,.75,1.05   VARIOUS CL
C     INTERPOLATE BETWEEN MT IS DM, OMU IS PU, CL IS PCC
C     NOTE IF BLADE IS STALLED ALPH 14 OR A1 SIGMA IS INCREASED
C     NOTE IF OMU IS HIGH ROTOR THRUST IS LOW PROP THRUST IS ADDED
C     IN READ (N1,J,K) N1 IS MT, J IS OMU, K 5 VALUES OF ALPH FOR EACH
C     OF 5 GROUPS OF CL CONTROLLED BY JJ
      IF(IREAD-1)86,70,70
   86 N1=1
      N2=6
    1 DO2J=1,N2
   87 FORMAT(1015)
      IA=1
      IB=5
      DO2JJ=1,5
      READ(5,104)(CDS(N1,J,K),K=IA,IB)
      READ(5,104)(CQS(N1,J,K),K=IA,IB)
      READ(5,104)(EAC(N1,J,K),K=IA,IB)
      READ(5,104)CLA(N1,J,JJ),CDM(N1,J,JJ)
      IA=IA+5
      IB=IB+5
    2 CONTINUE
      N1=N1+1
      IF(N1-3)3,3,4
    3 N2=4
      GOTO1
    4 IF(N1-4)5,5,6
    5 N2=3
      GOTO1
    6 WRITE(6,91)
      GOTO90
   91 FORMAT(1H ,11HBOE DATA IN)
   70 N1=1
      IF(TIPM-.77)7,7,8
    7 I1=1
      PM=(TIPM-.675)/.095
      GOTO11
    8 IF((TIPM/.875 )-1.)9,9,10
    9 I1=2
```

```
      PM=(TIPM-.77)/.105
      GOTO25
   10 I1=3
      PM=(TIPM-.875)/.075
      GOTO35
   11 IF(OMU-.5)12,12,13
   12 J1(N1)=1
      PU(N1)=(OMU-.2)/.3
      GOTO20
   13 IF(OMU-.8)14,14,15
   14 J1(N1)=2
      PU(N1)=(OMU-.5)/.3
      GOTO20
   15 IF(OMU-1.0)16,16,17
   16 J1(N1)=3
      PU(N1)=(OMU-.8)/.2
      GOTO20
   17 IF(OMU-1.2)18,18,19
   18 J1(N1)=4
      PU(N1)=(OMU-1.0)/.2
      GOTO20
   19 J1(N1)=5
      PU(N1)=(OMU-1.2)/.3
   20 X2=2
      N1=N1+1
   25 IF(OMU-.52)26,26,27
   26 J1(N1)=1
      PU(N1)=(OMU-.33)/.19
      GOTO30
   27 IF(OMU-.79)28,28,29
   28 J1(N1)=2
      PU(N1)=(OMU-.52)/.27
      GOTO30
   29 J1(N1)=3
      PU(N1)=(OMU-.79)/.37
   30 IF(N1-2)32,100,100
   32 X2=3
      N1=N1+1
   35 IF(OMU-.52)36,36,37
   36 J1(N1)=1
      PU(N1)=(OMU-.35)/.17
      GOTO40
   37 IF(OMU-.75)38,38,39
   38 J1(N1)=2
      PU(N1)=(OMU-.52)/.23
      GOTO40
   39 J1(N1)=3
      PU(N1)=(OMU-.75)/.3
   40 IF(N1-2)42,100,100
   42 X2=4
      N1=N1+1
   42 IF(OMU-.47)43,43,44
   43 J1(N1)=1
      PU(N1)=(OMU-.32)/.15
      GOTO100
   44 J1(N1)=2
      PU(N1)=(OMU-.47)/.19
  100 J=J1(1)
      I=I1
      DO54KK=1,4
```

```
      DO45KL=1,5
      N=KL
      IF(CLA(I,J,KL)-CL)45,45,46
   45 CONTINUE
   46 IF(N-1)47,47,48
   47 N=2
   48 DEN=CLA(I,J,N)-CLA(I,J,N-1)
      PCC(KK)=(CL-CLA(I,J,(N-1)))/DEN
      K1(KK)=1+5*N-5
      IF(KK-1)49,49,50
   49 J=J1(1)+1
      GOTO54
   50 IF(KK-2)51,51,52
   51 I=I+1
      J=J1(2)
      GOTO54
   52 IF(KK-3)53,53,54
   53 J=J1(2)+1
   54 CONTINUE
      I12=I1+1
      DO55  KK=1,5
      K11=K1(1)+KK-6
      K12=K11+5
      K13=K1(2)+KK-6
      K14=K13+5
      K15=K1(3)+KK-6
      K16=K15+5
      K17=K1(4)+KK-6
      K18=K17+5
      JX=J1(1)
      JY=J1(2)
      JW=JX+1
      JV=JY+1
      CD1=CDS(I1,JX,K11)*(1.-PCC(1))+PCC(1)*CDS(I1,JX,K12)
      CD2=CDS(I1,JW,K13)*(1.-PCC(2))+PCC(2)*CDS(I1,JW,K14)
      CD3=CDS(I12,JY,K15)*(1.-PCC(3))+PCC(3)*CDS(I12,JY,K16)
      CD4=CDS(I12,JV,K17)*(1.-PCC(4))+PCC(4)*CDS(I12,JV,K18)
      CD5=CD1+PU(1)*(CD2-CD1)
      CD6=CD3+PU(2)*(CD4-CD3)
      CD7(KK)=CD5+PM*(CD6-CD5)
      CQ1=CQS(I1,JX,K11)*(1.-PCC(1))+PCC(1)*CQS(I1,JX,K12)
      CQ2=CQS(I1,JW,K13)*(1.-PCC(2))+PCC(2)*CQS(I1,JW,K14)
      CQ3=CQS(I12,JY,K15)*(1.-PCC(3))+PCC(3)*CQS(I12,JY,K16)
      CQ4=CQS(I12,JV,K17)*(1.-PCC(4))+PCC(4)*CQS(I12,JV,K18)
      CQ5=CQ1+PU(1)*(CQ2-CQ1)
      CQ6=CQ3+PU(2)*(CQ4-CQ3)
      CQ7(KK)=CQ5+PM*(CQ6-CQ5)
      EAC1=EAC(I1,JX,K11)*(1.-PCC(1))+PCC(1)*EAC(I1,JX,K12)
      EAC2=EAC(I1,JW,K13)*(1.-PCC(2))+PCC(2)*EAC(I1,JW,K14)
      EAC3=EAC(I12,JY,K15)*(1.-PCC(3))+PCC(3)*EAC(I12,JY,K16)
      EAC4=EAC(I12,JV,K17)*(1.-PCC(4))+PCC(4)*EAC(I12,JV,K18)
      EA5=EAC1+PU(1)*(EAC2-EAC1)
      EA6=EAC3+PU(2)*(EAC4-EAC3)
   55 EA7(KK)=EA5+PM*(EA6-EA5)
      N11=(K1(1)+4)/5
      N12=N11-1
      N13=(K1(2)+4)/5
      N14=N13-1
      N15=(K1(3)+4)/5
      N16=N15-1
```

```
      N17=(K1(4)+4)/5
      N18=N17-1
      CD1=CDM(I1,JX,N12)*(1.-PCC(1))+PCC(1)*CDM(I1,JX,N11)
      CD2=CDM(I1,JW,N14)*(1.-PCC(2))+PCC(2)*CDM(I1,JW,N13)
      CD3=CDM(I12,JY,N16)*(1.-PCC(3))+PCC(3)*CDM(I12,JY,N15)
      CD4=CDM(I12,JV,N18)*(1.-PCC(4))+PCC(4)*CDM(I12,JV,N17)
      CD5=CD1+PU(1)*(CD2-CD1)
      CD6=CD3+PU(2)*(CD4-CD3)
      CDM7=CD5+PM*(CD6-CD5)
      DO57KK=1,5
      N=KK
      DEN=CD-CD7(KK)
      IF(CD-CD7(KK))57,157,157
   57 CONTINUE
      GOTO60
  157 IF(N-1)58,58,59
   58 N=2
   59 P=(CD-CD7(N-1))/(CD7(N)-CD7(N-1))
      AC=EA7(N-1)+P*(EA7(N)-EA7(N-1))
      CQ=CQ7(N-1)+P*(CQ7(N)-CQ7(N-1))
      GOTO89
   60 AC=10000.
C     AC=10000. FOR ROTOR CONDITION OF INADEQUATE THRUST
   89 CONTINUE
   88 FORMAT(3X7E15.8)
  104 FORMAT(10F10.5)
   90 RETURN
      END
*     LIST(STOP)
      LIST
*     DATA
0.    .02   .04   .06   .08   .10   .12   .14   .163  0.    .02   .04   .06
.08   .10   .12   .14   .162  0.    .02   .04   .06   .08   .10   .12   .14
.158  0.    .02   .04   .06   .08   .10   .12   .14   .154  0.    .02   .04
.06   .08   .10   .12   .14   .15   0.    .02   .04   .06   .08   .10   .12
.14   .146  0.    .02   .04   .06   .08   .10   .12   .14   .144  0.    .02
.04   .06   .08   .10   .12   .13   .14   0.    .02   .04   .06   .08   .10
.12   .13   .136  0.    .02   .04   .06   .08   .10   .12   .13   .133  0.
.02   .04   .06   .07   .08   .09   .1    .124  0.    .02   .04   .06   .07
.08   .09   .1    .12   0.    .02   .04   .06   .07   .08   .09   .10   .117
0.    .02   .04   .06   .07   .08   .09   .1    .114  0.    .02   .04   .06
.07   .08   .09   .1    .112
.00055.00162.00275.004  .0053 .007  .00875.0109 .015  .00055.0018 .0032 .0045
.0062 .008  .010  .0126 .0174 .00055.002  .0034 .0051 .0070 .0090 .0116 .015
.0190 .00055.0021 .0037 .0055 .0076 .0104 .0132 .017  .0204 .00055.0022 .0034
.006  .0082 .011  .0146 .0189 .0215 .00055.00162.00275.004  .0053 .0071 .0092
.012  .0134 .00055.0018 .0031 .0045 .0064 .0085 .011  .0145 .0155 .00055.0020
.0034 .0051 .0071 .0084 .0125 .0144 .0168 .0055 .0021 .0037 .0055 .0078 .0105
.014  .016  .018  .00055.0022 .004  .006  .0085 .0115 .0154 .018  .01871.0055
.00165.0028 .0042 .0049 .00575.00665.00775.0104 .00055.0018 .0032 .0049 .0058
.00675.0079 .0092 .0131 .00055.00195.0035 .00525.0064 .0076 .0088 .0105 .0140
.00055.0021 .0038 .0057 .0068 .0084 .0098 .0115 .0148 .00055.0022 .0040 .0060
.00725.0088 .0106 .0127 .0154
.00125     .0002      -.001      -.0025     -.0045                                1
.00084     .0019      .00149     .00183     .00233
10.        0.         -10.       -20.       -30.
.01        -80.
.00575     .001       -.003      -.00825    -.0145                                 2
.0001      .0019      .00203     .00307     .00441
10.        0.         -10.       -20.       -30.
```

.03	-60.			
.01375	.002	-.006	-.01475	-.02425
-.0003	.00119	.00277	.00455	.00658
10.	0.	-10.	-20.	-30.
.05	-60.			
.01825	.003	-.008	-.01975	-.03325
-.00084	.00139	.00376	.00614	.00921
10.	0.	-10.	-20.	-30.
.07	-50.			
.021	.00575	-.00925	-.024	-.0345
-.00109	.00183	.0047	.00817	.01064
10.	0.	-10.	-20.	-27.
.09	-33.			
.00131	.00082	.00033	0.	-.00131
.00117	.00142	.00176	.00209	.00318
10.	0.	-10.	-20.	-30.
.01	-70.			
.00311	.00147	-.00048	-.00245	-.00523
.0005	.00109	.00209	.00334	.00502
10.	0.	-10.	-20.	-30.
.02	-55.			
.00507	0.00213	-.00098	-.004780	-.00948
-.00042	.00075	.00242	.00451	.00736
10.	0.	-10.	-20.	-30.
.03	-40.			
.00703	.00327	-.00131	-.00638	-.01226
-.00134	.000307	.00268	.00527	.00903
10.	0.	-10.	-20.	-30.
.04	-31.			
.00916	.00409	-.00131	-.00752	-.0104
-.00334	.00008	.00268	.00602	.00752
10.	0.	-10.	-20.	-25.
.05	-25.			
.0032	.00205	.00184	.00184	.00226
.00132	.00148	.00158	.00158	.00158
12.	8.	4.	0.	-4.
.01	-17.5			
.0041	.00262	.00205	.00205	.00238
.00079	.00119	.00142	.00135	.00132
12.	8.	4.	0.	-4.
.02	-15.8			
.00525	.00361	.00262	.00258	.00246
.00132	.00059	.00106	.00106	.00116
12.	8.	4.	0.	-4.
.03	-10.5			
.00701	.00513	.00389	.00348	.00328
-.00106	-.0004	.00023	.00026	.00053
12.	8.	4.	0.	-4.
.04	-11.			
.01189	.00656	.00492	.00438	.00402
-.00201	-.00125	-.00053	-.0003	.00023
12.	8.	4.	0.	-4.
.05	-9.			
.00597	.00343	.00267	.00267	.00337
.00051	.00127	.00140	.00178	.00133
12.	8.	4.	0.	-4.
.01	-14.			
.00698	.00413	.00305	.00305	.00330
-.00127	.00089	.00140	.00127	.00051
12.	8.	4.	0.	-4.

.03	-9.5			
.00921	.00603	.00419	.00413	.00540
-.00171	-.00025	.00006	-.00025	0.
12.	8.	4.	0.	-4.
.05	-6.			
.0127	.00889	.00698	.00698	.0087
-.00381	-.00241	-.00152	-.00127	-.0002
12.	8.	4.	0.	-4.
.07	-3.3			
.01778	.0141	.01111	.0111	.0139
-.00711	-.00521	-.0033	-.00127	.0002
12.	8.	4.	0.	-4.
.09	-.5			
.00712	.00398	.00351	.00527	.00925
0.	.00495	.00165	.00088	-.00132
8.	4.	0.	-4.	-8.
.01	-12.			
.01027	.00481	.00370	.00416	.00601
0.	.00132	.00165	0.	-.0022
8.	4.	0.	-4.	-8.
.03	-7.			
.01341	.00666	.00388	.00462	.00555
-.00319	0.	.00132	.00066	-.00055
12.	8.	4.	0.	-2.
.05	-5.5			
.01554	.00897	.00555	.00065	.00786
-.00429	-.00110	.00022	-.0011	-.00165
12.	8.	4.	0.	1.
.07	-3.7			
.01536	.01221	.0086	.00999	.01258
-.0066	-.00341	-.00209	-.00165	-.00143
10.	8.	4.	0.	-1.
.09	-2.			
.01177	.00598	.0057	.00656	.00883
.0002	.00064	.0015	.00086	-.00021
4.	2.	0.	-2.	-4.
.01	-8.			
.00627	.00513	.00542	.00627	.00926
.0002	.0015	.00193	.00064	-.00064
4.	2.	0.	-2.	-4.
.03	-5.3			
.01083	.00593	.00513	.00556	.00812
-.00129	.00643	.00193	.00129	-.000143
8.	4.	2.	0.	-2.
.05	-4.3			
.01111	.00598	.0057	.00684	.001
-.00193	.00064	.00172	0.	-.00172
8.	4.	2.	0.	-2.
.07	-3.7			
.01111	.00613	.00656	.00855	.01126
-.00279	.00064	.00107	-.00172	-.00215
8.	4	2.	0.	1.
.09	-1.6			
.00173	.00028	-.00035	.00139	.00346
.00091	.00114	.00137	.00182	.00274
10.	0.	-10.	-20.	-30.
.01	-80.			
.00554	.00139	-.00277	-.00693	-.01247
-.00023	.001[illegible]3	.00239	.00376	.00593
10.	0.	-10.	-20.	-30.

.03	-58.			
.01039	.00278	-.00416	-.01247	-.0201
-.00068	.00068	.00235	.00559	.00866
10.	0.	10.	20.	30.
.05	-45.			
.01594	.00589	-.0045	-.01559	-.02772
-.00174	.00023	.00353	.00752	.01254
10.	0.	-10.	-20.	-30.
.07	-28.			
.01951	.00728	-.0045	-.01745	-.02979
-.00228	-.0004	.00388	.00906	.01444
5.	0.	-10.	-15.	-20.
.08	-20.			
.00177	.00133	.00009	.00018	-.00106
.00117	.0014	.00164	.00206	.00309
10.	0.	-10.	-20.	-30.
.01	-62.			
.00319	.00159	0.	-.00212	-.0046
.0004	.00112	.00187	.00318	.00486
10.	0.	-10.	-20.	-30.
.02	-48.			
.00478	.00195	-.00071	-.00372	-.00743
.00070	.00084	.00224	.0043	.00655
10.	0.	-10.	-20.	-30.
.03	-39.			
.0069	.00301	-.00089	-.00531	-.01062
-.0014	.00037	.00252	.00514	.00832
10.	0.	-10.	-20.	-30.
.04	-31.			
.0089	.00407	-.00106	-.00655	-.01292
-.00182	-.00009	.00262	.00608	.01066
5.	0.	-10.	-20.	-30.
.05	-23.			
.00211	.00179	.00239	.00386	.00478
.00159	.00159	.00147	.00098	.00098
8.	0.	-5.	-10.	-15.
.01	-16.			
.00235	.00223	.00219	.00318	.00386
.00122	.00135	.00153	.00129	.00092
8.	0.	-5.	-10.	-15.
.02	-12.			
.00541	.00287	.00271	.00239	.00316
.00006	.00092	.00101	.00138	.00138
12.	5.	0.	-5.	-10.
.03	-12.			
.00689	.00398	.00342	.0033	.00318
-.00083	.00024	.00043	.00098	.00141
12.	5.	0.	-5.	-10.
.04	-11.			
.00864	.00549	.00438	.00386	.00366
-.00184	-.00061	-.00024	.00061	.00181
12.	5.	0.	-5.	-10.
.05	-9.5			
.01533	.00361	.00344	.00568	.01178
.00105	.00136	.0021	.00084	-.00158
8.	4.	0.	-5.	-10.
.01	-13.			
.00568	.00473	.00344	.00559	.01161
.00084	.00126	.00168	.00084	-.00147
8.	4.	0.	-5.	-10.

.03	-8.			
.00568	.00378	.00499	.00654	.00946
-.00116	.00147	.00042	.0002	.00084
8.	4.	0.	-3.	-6.
.05	-5.7			
.01144	.00602	.000662	.00877	.01238
-.00252	.00021	-.00063	.00021	-.00179
10.	5.	0.	-3.	-6.
.07	-4.			
.01428	.00851	.00791	.00955	.01273
-.00431	-.00168	-.00168	-.00126	.00126
10.	5.	3.	0.	-3.
.09	-2.			
.00198	.00103	.00039	-.00119	-.00356
.00111	.00139	.00167	.00222	.00334
10.	0.	-10.	-20.	-30.
.01	-80.			
.00592	.00198	-.00047	-.00632	-.01146
[illegible]	.00139	.00278	.00417	.00612
10.	0.	-10.	-20.	-30.
.03	-70.			
.01027	.0034	-.00348	-.01082	-.01935
-.00139	.00106	.00334	.00612	.00973
10.	0.	-10.	-20.	-30.
.05	-55.			
.01303	.00442	-.00395	-.01224	-.02291
-.00195	.00080	.00400	.00723	.01182
10.	0.	-10.	-20.	-30.
.06	-47.			
.01619	.00632	-.00395	-.01422	-.02528
-.00306	.00056	.00403	.00834	.01557
10.	0.	-10.	-20.	-30.
.07	-25.			
.0023	.00159	.00124	.00071	-.00057
.00181	.00199	.00238	.00371	.00541
10.	0.	-10.	-20.	-30.
.01	-57.			
.00372	.00186	.00053	-.00142	-.00407
.00109	.00181	.00238	.00352	.00542
10.	0.	-10.	-20.	-30.
.02	-48.			
.00549	0.00266	0.	-.00319	-.00726
.0002	.00143	.00266	.00475	.00741
10.	0.	-10.	-20.	-30.
.03	-39.			
.00766	.00275	-.00004	-.00478	-.01027
-.00076	.00095	.00285	.00570	.00931
10.	0.	-10.	-20.	-30.
.04	-31.			
0.00991	0.00478	-.00035	-.0062	-.0094
-.00199	.00028	.00314	.00665	.0095
10.	0.	-10.	-20.	-25.
.05	-23.			
.0048	.00333	.00343	.00519	.01
.00413	.00409	.00370	.00335	.00279
12.	6.	0.	-8.	-20.
.01	-19.			
.00568	.00342	.00343	.00392	.00598
.00335	.00337	.00348	.00361	.00370
12.	6.	0.	-8.	-20.

.02	-17.8			
.00686	.00451	.00392	.00392	.00510
.00249	.00322	.00344	.00387	.00434
12.	6.	0.	-8.	-16.
.03	-16.			
.0098	.00666	.00534	.00441	.00466
.00034	.00163	.00224	.00335	.00473
12.	6.	0.	-6.	-12.
.04	-11.			
.01372	.00931	.0076	.00637	.00539
-.00241	-.00043	.00077	.0031	.00464
12.	6.	0.	-6.	-10.
.05	-9.			
.00674	.00483	.00412	.00625	.01022
.00283	.00224	.00305	.00231	.00015
10.	6.	0.	-6.	-12.
.01	-12.5			
.00994	.00483	.00454	.00674	.01235
.00052	.00276	.00276	.00209	.00075
12.	6.	0.	-6.	-12.
.03	-8.5			
.01193	.00625	.00554	.00596	.00817
-.00037	.002[illegible]1	.00224	.00164	.00224
12.	6.	3.	0.	-4.
.05	-5.7			
.01526	.00923	.00795	.0088	.01122
-.00238	.0004	.00224	.00596	.00283
12.	6.	3.	0.	-3.
.07	-1.			
.0186	.01235	.0118	.01257	.01463
-.00447	-.00209	-.00112	.00127	.00343
12.	6.	3.	0.	-3.
.09	-80.			
.00307	.00192	.00004	-.00109	-.00307
.00223	.00244	.00325	.00294	.00355
10.	0.	-10.	-20.	-30.
.01	-70.			
.00685	.00307	-.0016	-.0064	-.01152
.00091	.00263	.00345	.00487	.0065
10.	0.	-10.	-20.	-30.
.03	-45.			
.00112	-.00397	-.00307	-.0112	-.01984
-.00041	.00173	.00416	.007	.01035
10.	0.	-10.	-20.	-30.
.05	-28.			
.01664	.0064	-.00397	-.01472	-.02637
-.00162	.00142	.00518	.00954	.01563
10.	0.	-10.	-20.	-30.
.07	-19.			
.01971	.00794	-.00384	-.0096	-.016
-.00223	.00158	.00599	.00832	.01157
10.	0.	-10.	-20.	-30.
.08	-68.			
-.00335	-.00251	-.00181	-.00098	.00056
.00262	.00275	.00294	.00334	.00438
10.	0.	-10.	-20.	-30.
.01	-46.			
.0067	.00349	.0007	-.00377	-.00809
.00098	.00229	.00379	.00549	.00798
10.	0.	-10.	-20.	-30.

```
.03       -36.
.00893    .00413    -.00042   -.0053    -.01116
.0004     .00196    .00405    .00719    .01033
10.       0.        -10.      -20.      -30.
.04       -28.
.01144    .00558    -.00042   -.00684   -.01395
-.00078   -.00144   .00432    .00778    .01243
10.       0.        -10.      -20.      -30.
.05       -20.
.01381    .00698    -.00014   -.00405   -.00767
.00196    .00098    .00445    .00654    .00883
10.       0.        -10.      -20.      -25.
.06       -52.
.0053     .00394    .00316    .00394    .00438
.0042     .0051     .0066     .00495    .0044
20.       10.       0.        -10.      -20.
.01       -53.
.00393    .00349    .00238    .00127    -.00055
.00348    .00379    .00512    .00659    .00997
0.        -10.      -20.      -30.      -40.
.02       -45.
.00465    .00316    .00122    -.00105   -.00377
.00275    .00384    .00604    .00878    .01363
0.        -10.      -20.      -30.      -40.
.03       -38.
.00543    .00366    .00022    -.00111   -.00249
.00229    .00412    .00714    .00906    .01153
0.        -10.      -20.      -25.      -30.
.04       -29.
.01.5     .00638    .00332    .00166    -.00014
-.00037   -.0023    .0042     .0062     .0090
10.       0.        -10.      -15.      -20.
.05       -15.
7100.     24.       0.        .645      .0651     22.       1155.
.00222    -.5       6.        .8        600.      10.9      18.5
27.       0.        .1.5      4.3       -.0525
1.        10.       1.        0.
```

TABLE A-2

```
C              STRIP ROTOR THEORY STABILITY DERIVATIVES
C          LIST OF INPUT CARDS (AFTER 130 AIRFOIL SECTION DATA CARDS)
C CD   COL    SYMBOL
C  1   0-8    TC         COLLECTIVE PITCH         DEG.
C  1   9-16   OMU        TIP SPEED RATIO
C  1  17-24   VT         TIP SPEED                F.P.S.
C  1  25-32   SIG        ROTOR SOLIDITY
C  1  33-40   AK         ROTOR ANGLE OF ATTACK    DEG.
C  1  41-48   D3         DELTA 3                  DEG.
C  1  49-56   B          NUMBER OF BLADES
C  1  57-64   R          ROTOR  RADIUS            FT.
C  1  65-72   RHO        DENSITY
C  2   0-8    DS         SHAFT ANGLE              DEG.
C  2   9-16   XR         HORIZONTAL ARM C.G. TO SHAFT    FT.  + UP
C  2  17-24   HR         VERTICAL ARM C.G. TO SHAFT      FT.  - FWD
C  2  25-32   ET         TAIL LENGTH                     FT.
C  2  33-40   VTT        TAIL ROTOR TIP SPEED            F.P.S
C  2  41-48   SIGT       TAIL ROTOR SOLIDITY
C  2  49-56   RT         TAIL ROTOR RADIUS               FT.
C  2  57-64   SVT        AREA VERTICAL TAIL              SQ.FT.
C  2  65-72   SHT        AREA HORIZONTAL TAIL            SQ.FT.
C  3   0-8    VOLF       FUSELAGE VOLUME                 CU.FT.
C  3   9-16   CDA        FUSELAGE DRAG AREA              SQ.FT.
C  3  17-24   EC         ROTOR BLADE HINGE ECCENTRICITY  EC/R
C     TYPE OF ROTOR     EC=0. FOR TEETERING
C                       EC=GT.0.LT1. FOR ARTICULATED
C                       EC=2. FOR RIGID
C                       EC=3.0 FOR RESTRICTED TEETERING
C  4  25-32              TORSION SPRING RATE FOR EC=3.0
C     D3 IS DELTA 3 FUTURE USE NOW 0
      DIMENSIONCDR(18,5),CDT(18,5)
      DIMENSIONCL1(91,5),CD1(91,5)
      DIMENSION C1(2),C2(2),E3(2)
      DIMENSION E8(10),E9(10),C20(3)
      DIMENSION CC(12,7),UX(12,7),CB(12,7),CVT(12,7),CHT(12,7),CTR(12,7)
      DIMENSION C10(2),C11(2),C12(2),C13(2),C14(2),C15(2),C16(2),C17(2)
      DO13J=1,5
      READ(5,1)(CL1(I,J),I=1,91)
      READ(5,1)(CD1(I,J),I=1,91)
      READ(5,1)(CDT(I,J),I=1,18)
      READ(5,1)(CDR(I,J),I=1,18)
      WRITE(6,1)(CL1(I,J),I=1,91)
      WRITE(6,1)(CD1(I,J),I=1,91)
      WRITE(6,1)(CDT(I,J),I=1,18)
      WRITE(6,1)(CDR(I,J),I=1,18)
   13 CONTINUE
      WRITE(6,6)
    6 FORMAT(15X,35HALL COEFFICIENTS BASED ON DISC AREA)
      WRITE(6,5)
   20 READ(5,2) TC,OMU,VT,SIG,AK,D3,B,R,RHO
      READ(5,4)DS,XR,HR,ET,VTT,SIGT,RT,SVT,SHT
      READ(5,7) VOLF,CDA,EC,RK
    4 FORMAT(4F8.2,F8.0,F8.3,3F8.1)
    7 FORMAT(3F8.2,E15.8)
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```
      WRITE(6,5)
      WRITE(6,2)TC,OMU,VT,SIG,AK,D3,B,R,RHO
      WRITE(6,4)DS,XR,HR,ET,VTT,SIGT,RT,SVT,SHT
      WRITE(6,7)VOLF,CDA,EC,RK
      WRITE(6,152)
      DS=DS/57.3
      V=OMU*VT
      AS=-12.  $DAS=4.                  $SK=SK/57.3
      SY=-15.  $DSY=15.  $TB=TC/57.3
      J3=7
    1 FORMAT(9F8.5)
    2 FORMAT(2F8.5,F8.0,2F8.5,2F8.1,F8.2,F8.5)
    3 FORMAT(3F8.3,5F10.5)
    5 FORMAT(/)
      RC=SIG*3.141*R*R/B
      BIN=0.
      WB=2.28*RC**1.164
      G=BIN/(RHO*3.141*2.7*VT**2*R**3)
      G1=WB*B/(RHO*32.2*.50*3.141*R**3)
      CRK=RK/(RHO*3.141*R**3*VT**2)
      G2=CRK
      IF(AK)30,31,30
   30 AS=AK-DAS  $J3=1
   31 CONTINUE
C     ALPHA LOOP
      DO102 JN=1,J3
      AS=AS+DAS  $AA=AS/57.3
      CR=0.  $CP=0.  $CW=0.  $CU=0  $CV=0.
      A1=-1.  $B1=-1.
      SK=0.
      DO 32 I=1,12
      DO 32 J=1,7
      CTR(I,J)=0.
      CVT(I,J)=0.
      CHT(I,J)=0.
      CB(I,J)=0.
   32 CC(I,J)=0.
      DO 107 L1=1,2
      A1=A1+1.
      SM=A1/57.3
      CALL NO(TB,OMU,VT,SIG,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CTSS,
     1CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
      E9(L1)=SV
      C20(L1)=CMYSS  $C11(L1)=CMXSS  $C12(L1)=CYSS
      C16(L1)=CDSS
      C13(L1)=CTSS  $C14(L1)=CHSS  $C15(L1)=CQSS  $C17(L1)=CLSS
  107 CONTINUE
      CMYDA=C20(2)-C20(1)  $CTDA=C13(2)-C13(1)
      CXDA=-(C16(2)-C16(1))
      CMXDA=C11(2)-C11(1)  $CHDA=C14(2)-C14(1)
      CYDA=C12(2)-C12(1)   $CQDA=C15(2)-C15(1)
      SM=0.
      IF(CMXDA.NE.0.) SM=-C11(1)/(57.3*CMXDA)
      DO 108 L1=1,2
      B1=B1+1.
      SK=B1/57.3
      CALL NO(TB,OMU,VT,SIG,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CTSS,
     1CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
      C20(L1)=CMYSS  $C11(L1)=CMXSS  $C12(L1)=CYSS  $C16(L1)=CDSS
      C13(L1)=CTSS  $C14(L1)=CHSS  $C15(L1)=CQSS  $C17(L1)=CLSS
```

```
108 CONTINUE
    CMYDB=C20(2)-C20(1)  $CTDB=C13(2)-C13(1)
    CXDB=-(C16(2)-C16(1))
    CMXDB=C11(2)-C11(1)  $CHDB=C14(2)-C14(1)
    CYDB=C12(2)-C12(1)  $CQDB=C15(2)-C15(1)
    SK=0.
    IF(CMYDB.NE.0.) SK=-C20(1)/(57.3*CMYDB)
    CALL ND(TB,DMU,VT,SIG,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CTSS,
   1CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
    C10(1)=CMYSS   $C11(1)=CMXSS   $C12(1)=CYSS   $C16(1)=CDSS
    C13(1)=CTSS    $C14(1)=CHSS    $C15(1)=CQSS   $C17(1)=CLSS
    B1=SK*57.3  $A1=SM*57.3
    WRITE(6,166)
166 FORMAT(5X,29HFINAL VALUES IN PREVIOUS LINE)
    WRITE(6,152)
    WRITE(6,150)
150 FORMAT(1X,5HSHAFT,4X,4HCOLL,6X,3HLAT,5X,5HPITCH,4X,3HTIP,4X,5HSPEE
   1D)
    WRITE(6,151)
151 FORMAT(1X,5HANGLE,4X,5HPITCH,5X,4HTRIM,4X,4HTRIM,4X,5HSPEED,4X,5HR
   1ATIO)
    WRITE(6,10)AS,TC,A1,B1,VT,DMU
 10 FORMAT(4F8.2,F8.0,F8.3)
 11 FORMAT(15X,7E15.8)
    WRITE(6,152)
152 FORMAT(/)
 15 FORMAT(10X,13HIN ROTOR AXIS)
    WRITE(6,15)  $WRITE(6,152)
    WRITE(6,153)
153 FORMAT(5X,7HYAW MOM,6X,9HPITCH MOM,6X,8HROLL MOM,6X,10H    Y     ,
   18X,6H  Z   ,8X,5H  X  ,10X,6HTORQUE)
    WRITE(6,154)
154 FORMAT(5X,24HLAT CYCLIC EFFECTIVENESS)
    WRITE(6,11)CMYDA,CMXDA,CYDA,CTDA,CHDA,CQDA
    WRITE(6,155)
155 FORMAT(5X,26HPITCH CYCLIC EFFECTIVENESS)
    WRITE(6,11)CMYDB,CMXDB,CYDB,CTDB,CHDB,CQDB
    CC(1,1)=CMYDA  $CC(1,2)=CMXDA  $CC(1,3)=CYDA
    CC(1,4)=CTDA   $CC(1,5)=CXDA   $CC(1,6)=CQDA
    CC(2,1)=CMYDB  $CC(2,2)=CMXDB  $CC(2,3)=CYDB
    CC(2,4)=CTDB   $CC(2,5)=CXDB   $CC(2,6)=CQDB
    J1=2.
    TB1=TB+1./57.3
    DO99JJ=1,6
    J1=J1+1
    CR=0. $CP=0.  $CW=0.  $CU=0.  $CV=0.
    IF(JJ.EQ.1) CR=1./57.3
    IF(JJ.EQ.2) CP=-1./57.3
    IF(JJ.EQ.3)CU=-1.
    IF(JJ.EQ.4)CW=1.
    IF(JJ.EQ.5)CV=+1.
    IF(JJ.EQ.6)TB=TB1
    CALL ND(TB,DMU,VT,SIG,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CTSS,
   1CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
    E8(JJ)=SV
    C10(2)=CMYSS  $C11(2)=CMXSS  $C12(2)=CYSS
    C16(2)=CDSS
    C13(2)=CTSS   $C14(2)=CHSS   $C15(2)=CQSS
    CMYD=C10(2)-C10(1)  $CTD=C13(2)-C13(1)
    CXD=-(C16(2)-C16(1))
```

```
      CMXD=C11(2)-C11(1)  $CHD=C14(2)-C14(1)
      CYD=C12(2)-C12(1)   $CQD=C15(2)-C15(1)
      WRITE(6,152)
      WRITE(6,153)
      IF(JJ.EQ.1) WRITE(6,157)
      IF(JJ.EQ.2) WRITE(6,158)
      IF(JJ.EQ.3) WRITE(6,160)
      IF(JJ.EQ.4) WRITE(6,159)
      IF(JJ.EQ.5) WRITE(6,161)
      IF(JJ.EQ.6)WRITE(6,163)
      IF(JJ.EQ.6)TB=TB1-1./57.3
      WRITE(6,11)CMYD,CMXD,CYD,CXD,CQD
      CC(J1,1)=CMYD  $CC(J1,2)=CMXD  $CC(J1,3)=CYD
      CC(J1,4)=CTD   $CC(J1,5)=CHD   $CC(J1,6)=CQD
      IF(JJ.EQ.6)GOTO99
      IF(JJ-4)99,162,162
  162 CMYD=CMYD*V  $CMXD=CMXD*V  $CYD=CYD*V  $CTD=CTD*V
      CHD=CHD*V  $CQD=CQD*V
      CXD=CXD*V
      IF(JJ.EQ.4)WRITE(6,164)
      IF(JJ.EQ.5)WRITE(6,165)
      WRITE(6,11)CMYD,CMXD,CYD,CTD,CXD,CQD
      J1=J1+1
      CC(J1,1)=CMYD  $CC(J1,2)=CMXD  $CC(J1,3)=CYD
      CC(J1,4)=CTD   $CC(J1,5)=CXD   $CC(J1,6)=CQD
   99 CONTINUE
  163 FORMAT(5X,10HCOLLECTIVE)
  164 FORMAT(5X,15HANGLE OF ATTACK)
  165 FORMAT(5X,8HSIDESLIP)
  157 FORMAT(5X,12HROLL DAMPING)
  158 FORMAT(5X,13HPITCH DAMPING)
  159 FORMAT(5X,17HVERTICAL VELOCITY)
  160 FORMAT(5X,16HFORWARD VELOCITY)
  161 FORMAT(5X,13HSIDE VELOCITY)
      WRITE(6,152)  $WRITE(6,40)  $WRITE(6,152)
      WRITE(6,150)
      WRITE(6,151)
      WRITE(6,10)AS,TC,A1,B1,VT,OMU
      WRITE(6,152)
      WRITE(6,153)
      DO41 I=1,4
      DO41 J=1,7
   41 CC(I,J)=CC(I,J)*57.3
      DO42J=1,7
   42 CC(10,J)=CC(10,J)*57.3
      CALL PRNT (CC)
   40 FORMAT(10X,15HSUMMARY OF DATA)
      A54=CC(5,4)  $A64=CC(6,4)  $A55=CC(5,5)  $A65=CC(6,5)
C         CHANGES ROTOR DERIVATIVES TO STABILITY AXIS
      CC(5,4)=-(A54-A64*DS)-(A55-A65*DS)*DS
      CC(5,5)=-(A54-A64*DS)*DS+(A55-A65*DS)
      CC(6,4)=-(A64+A54*DS)-(A65+A55*DS)*DS
      CC(6,5)=-(A64+A54*DS)*DS+(A65+A55*DS)
      CC(5,1)=-HR*CC(5,5)/R-XR*CC(5,4)/R
      CC(6,1)=-HR*CC(6,5)/R-XR*CC(6,4)/R
      CC(1,4)=-CC(1,4)
      CC(2,4)=-CC(2,4)
      CC(3,4)=-CC(3,4)
      CC(4,4)=-CC(4,4)
      CC(7,4)=-CC(7,4)
```

```
      CC(8,4)=-CC(8,4)
      CC(9,4)=-CC(9,4)
      CC(10,4)=-CC(10,4)
      CC( 1,2)=CC( 1,2)+CC( 1,3)*HR/R
      CC( 2,2)=CC( 2,2)+CC( 2,3)*HR/R
      CC( 3,2)=CC( 3,2)+CC( 3,3)*HR/R
      CC( 4,2)=CC( 4,2)+CC( 4,3)*HR/R
      CC( 5,2)=CC( 5,2)+CC( 5,3)*HR/R
      CC( 6,2)=CC( 6,2)+CC( 6,3)*HR/R
      CC( 8,2)=CC( 8,2)+CC( 8,3)*HR/R
      CC(10,2)=CC(10,2)+CC(10,3)*HR/R
      CC(11,2)=CC(11,2)+CC(11,3)*HR/R
      CC( 1,1)=CC( 1,1)+CC( 1,4)*XR/R-CC( 1,5)*HR/R
      CC( 2,1)=CC( 2,1)+CC( 2,4)*XR/R-CC( 2,5)*HR/R
      CC( 3,1)=CC( 3,1)+CC( 3,4)*XR/R-CC( 3,5)*HR/R
      CC( 4,1)=CC( 4,1)+CC( 4,4)*XR/R-CC( 4,5)*HR/R
      CC( 5,1)=CC( 5,1)+CC( 5,4)*XR/R-CC( 5,5)*HR/R
      CC( 6,1)=CC( 6,1)+CC( 6,4)*XR/R-CC( 6,5)*HR/R
      CC( 8,1)=CC( 8,1)+CC( 8,4)*XR/R-CC( 8,5)*HR/R
      CC(10,1)=CC(10,1)+CC(10,4)*XR/R-CC(10,5)*HR/R
      CC(11,1)=CC(11,1)+CC(11,4)*XR/R-CC(11,5)*HR/R
      DO 14 I=1,10
   14 CC(I,7)=0.
      CC(10,7)=-CC(10,3)*XR/R
      CC(1,7)=-CC(1,3)*XR/R
      CC(2,7)=-CC(2,3)*XR/R
C     CHANGES TO COMPLETE MODEL
C         TAIL ROTOR
      OMUT=OMU*VT/VTT
      TB=0.  $SK=0.  $SM=0.  $AA=0.  $CR=0.  $CP=0.  $CW=0.
      CU=0.  $CV=0.  $D3=0.  $EC=2.
      CALL NO(TB,OMUT,VTT,SIGT,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CT
     1SS,CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,RT,G2,HR)
      CTB=CTSS
      TB=1./57.3
      CALL NO(TB,OMUT,VTT,SIGT,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CT
     1SS,CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,RT,G2,HR)
      CTTB=(CTSS-CTB)*57.3
      CW=1.
      TB=0.
      CALL NO(TB,OMUT,VTT,SIGT,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS,CT
     1SS,CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,RT,G2,HR)
      CTW=CTSS-CTB
      TRR=(RT*VTT/(R*VT))**2.
      YVT=-CTW*TRR        $ZVT=-YVT*ET/R      $YBTT= V*YVT    $ZBTT=ZVT*V
      YTCT=CTTB*TRR       $ZTCT=-YTCT*ET/R
      YSDT=-ET*YVT        $ZSDT=-YSDT*ET/R
      HT=5.
      YTDT=YVT*HT
      ZTDT=-YTDT*ET/R
C         VERTICAL TAIL
      CLAT=2.0                                   $QC=VT*VT*3.1416*R*R
      EVT=CLAT*V*V*SVT/2.  $YBTVT=-EVT/QC
          ZBTVT=0.  $YVVT=0.  $ZVVT=0.
      IF(V.LT.1.) GOTO8
      ZBTVT=EVT*ET/(QC*R)  $YVVT=YBTVT/V  $ZVVT=ZBTVT/V
    8 CONTINUE
      YSDVT=-YVVT*ET  $ZSDVT=-ZVVT*ET
C         HORIZONTAL  TAIL
      CLAT=2.6
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      EHT=CLAT*    V*V*SHT/2.
      ZAHT=-EHT*(1.-(E8(4)-E9(1)))/QC
      ZWHT=0.
      ZTHDT=0.
      IF(V.GT.1.) ZWHT=ZAHT/V
      IF(V.GT.1.) ZTHDT=-EHT*ET/(QC*V)
      CMAHT=ZAHT*ET/R
      CMWHT=ZWHT*ET/R
      CMTDHT=ZTHDT*ET/R
C         BODY
      CXU=-CDA*V/(  R*VT*VT)
          HF=.8
      CMAF=2.*HF*VOLF*(1.-(E8(4)-E9(1)))/(3.141*R**3.)
      CNBF=2.*HF*VOLF/(3.141*R**3.)
      CMAF=CMAF*V*V/(2.*VT*VT)
      CNBF=CNBF*V*V/(2.*VT*VT)
      CMWF=0.
      CNVF=0.
      IF(V.GT.0.) CMWF=CMAF/V
      IF(V.GT.0.) CNVF=-CNBF/V
      CTR(8,3)=YVT$ CTR(8,7)=ZVT
      CTR(9,3)=YBTT$ CTR(9,7)=ZBTT
      CTR(12,3)=YTCT$ CTR(12,7)=ZTCT
      CTR(11,3)=YSDT$ CTR(11,7)=ZSDT
      CTR(3,3) =YVT*HT
      CTR(3,7)=ZTDT
      CTR( 3,2)=-CTR( 3,7)*HT/ET
      CTR( 8,2)=-CTR( 8,7)*HT/ET
      CTR( 9,2)=-CTR( 9,7)*HT/ET
      CTR(11,2)=-CTR(11,7)*HT/ET
      CTR(12,2)=-CTR(12,7)*HT/ET
      CVT(8,3)=YVVT$ CVT(8,7)=ZVVT
      CVT(9,3)=YBTVT$ CVT(9,7)=ZBTVT
      CVT(11,3)=YSDVT$ CVT(11,7)=ZSVDT
      CHT(7,4)=ZAHT$ CHT(6,4)=ZWHT
      CHT(7,1)=CMAHT$ CHT(6,1)=CMWHT
      CHT(4,1)=CMTDHT$ CHT(4,4)=ZTHDT
      CB(5,5)=CXU
      CVT( 8,2)=CVT( 8,7)*HT/(2.*ET)
      CVT( 9,2)=-CVT( 9,7)*HT/(2.*ET)
      CVT(11,2)=-CVT(11,7)*HT/(2.*ET)
      CVT( 3,3)=CVT( 8,3)*HT/2.
      CVT( 3,2)=CVT( 3,3)*HT/(2.*R)
      CVT( 3,7)=CVT( 3,3)*ET/(-R)
      CB(7,1)=CMAF$ CB(6,1)=CMWF
      CB(9,7)=CNBF$ CB(8,7)=CNVF
      WRITE(6,152)$ WRITE(6,16)$ WRITE(6,152)
      WRITE(6,153)$ WRITE(6,152)
   33 FORMAT(5X,18HMAIN ROTOR PER DEG)
   34 FORMAT(5X,4HBODY)
   35 FORMAT(5X,13HVERTICAL TAIL)
   36 FORMAT(5X,15HHORIZONTAL TAIL)
   37 FORMAT(5X,10HTAIL ROTOR)
   38 FORMAT(5X,16HTOTAL PER RADIAN)
      WRITE(6,33)
      CALL PRNT(CC)
      WRITE(6,34)
      CALL PRNT(CB)
      WRITE(6,35)
      CALL PRNT(CVT)
```

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      WRITE(6,36)
      CALL PRNT(CHT)
      WRITE(6,37)
      CALL PRNT(CTR)
      DO 39 I=1,12
      DO 39 J=1,7
   39 CC(I,J)=CC(I,J)+CB(I,J)+CVT(I,J)+CHT(I,J)+CTR(I,J)
      WRITE(6,38)
      CALL PRNT(CC)
  102 CONTINUE
   16 FORMAT(10X,17HIN STABILITY AXIS)
      GOTO20  $END
      SUBROUTINE NO(TB,OMU,VT,SIG,SK,SM,AA,CL1,CDR,CMYSS,CMXSS,CYSS,CDSS
     1,CTSS,CHSS,CQSS,CLSS,CR,CP,CW,CU,CV,D3,G,CD1,CDT,SV,EC,G1,R,G2,HR)
      DIMENSIONCDR(18,5),CDT(18,5)
      DIMENSIONCL1(91,5),CD1(91,5)
      DIMENSION C1(2),C2(2),E3(2)
      DIMENSION C10(2),C11(2),C12(2),C13(2),C14(2),C15(2),C16(2),C17(2)
      DIMENSION B6(24),B7(24),B10(24)
      DO 8 J7=1,24
      B6(J7)=0.
      B10(J7)=0.
    8 B7(J7)=0.
      CRK=G2
      J=1
      DT=VT*57.3/(R*15.)
      DT=1./DT
  152 FORMAT(/)
      DSY=15.  $SY=-15.
      TC=TB*57.3
      AS=AA*57.3
      C=1120.
      SMF=.014
      SV=5.
      BLAM=0.
      SF=OMU*SIN(AA)
      S2=SF*SF
      O2=OMU*OMU
C     INDUCED VELOCITY LOOP
    4 FORMAT(3F10.3,4F10.5,F10.3)
      DO101JJ=1,5
      IF(SV.GT.110.) SV=100.+.1*SV
      DO99IJ=1,2
      E1=SV/VT
      E2=E1*E1
      E3(IJ)=E1
      C2(IJ)=SQRT(4.*E2*(O2+S2-2.*SF*E1+E2))
      IF(SV.LT.0.) C2(IJ)=-C2(IJ)
   14 FORMAT(4X,2HAS,7X,2HSY,8X,3HAL2,8X,3HCLU,7X,3HCDU,6X,4HSPAN,7X,3HS
     1TM)
      IF(JJ-5)22,21,22
   21 WRITE(6,14)
   22 CONTINUE
      IF(J.EQ.1)GO TO 12
      DO 10 J7=1,24
      N1=J7-1
      IF(N1.EQ.0) N1=24
      N2=J7+1
      IF(N2.EQ.25)N2=1
      B8=(B7(J7)-B7(N1))/DT
```

```
      B9=(B7(N2)-B7(J7))/DT
   10 B6(J7)=(B8+B9)/2.
      DO 11 J7=1,24
      N1=J7-1
      IF(N1.EQ.0) N1=24
      N2=J7+1
      IF(N2.EQ.25)N2=1
      B8=(B6(J7)-B6(N1))/DT
      B9=(B6(N2)-B6(J7))/DT
   11 B10(J7)=(B8+B9)/8.
   12 CONTINUE
      DO107LK=1,2
      CISS=0.  $CHSS=0.
      SY=-15.
C     AZIMUTH LOOP
      CMXSS=0.  $CMYSS=0.  $CYSS=0.
      CTSS=0.  $CDSS=0.  $COSS=0.
      DO100KJ=1,24
      SY=SY+DSY  $SA=SY/57.3
      DTH=0.  $B1=0.
      BQ=0.
      AR=EC
      IF(EC.GT.1.) AR=0.
      CTS=0.   $CPS=0.  $CHS=0.
      CMX=0.  $CMY=0.  $CYS=0.
      CRS=0.
C     SPAN LOOP
      DTH=B7(JK)*D3/(57.3*8.)
      BP=57.3*B7(KJ)
      DO103KK=1,8
      DAR=(1.-EC)/8.
      IF(EC.GT.1.) DAR=.125
      IF(KK.EQ.1) DAR=DAR/2.
      AR=AR+DAR
      IF(AR.EQ.0.) AR=.0625
C     FOR THD/OMEGA RATES
      VY=DMU*VT*SIN(AA)-SV+AR*R *(CR*SIN(SA)+CP*COS(SA))+CW
      VY=VY+AR*R*B6(JK)
      VX=VT*(AR+DMU*SIN(SA)*COS(AA))+CU*SIN(SA)+CV*COS(SA)
      STM=ABS(VX)/C  $IM=STM/.2
      IF(IM)28,27,28
   27 IM=1  $PM=0.  $IMM=2
      GOTO29
   28 IMM=IM+1  $AUM=IM  $AJM=AUM*.2  $PM=(STM-AUM)/.2
   29 CONTINUE
      GA=ABS(VY/VX)
C     AH LOCAL ANGLE OF ATTACK RELATIVE WIND TO PLANE PERPINDICULAR TO SHAFT
      AH=ATAN(GA)
      IF(VY)41,40,40
   40 IF(VX)44,43,43
   44 AH=3.141-AH  $GOTO43
   41 IF(VX)46,45,45
   45 AH=-AH  $GOTO43
   46 AH=AH-3.141
   43 AH=AH
      TT=-8.*AR/57.3   $FN=1.
      SB=SA-D3/57.3
      AL1=TB+6./57.3+TT-SM*SIN(SB)+SK*COS(SB)-DTH+AH
      IF(AL1)47,49,49
   47 AL1=-AL1  $FN=-1.
```

```
   49 AL2=AL1*57.3
      ID=AL2/2.+1.
      AUS=ID*2
      PU=1.-(AUS-AL2)/2.
C     CLU, CDU LOCAL LIFT AN DRAG COEFFICIENTS
      IDD=ID+1
      CL3=(CL1(ID,IM)+PU*(CL1(IDD,IM)-CL1(ID,IM)))*FN
      CD3=(CD1(ID,IM)+PU*(CD1(IDD,IM)-CD1(ID,IM)))
      CL4=FN*(CL1(ID,IMM)+PU*(CL1(IDD,IMM)-CL1(ID,IMM)))
      CD4=CD1(ID,IMM)+PU*(CD1(IDD,IMM)-CD1(ID,IMM))
      IF(ID-17)33,33,37
   33 IF(KK-6)34,34,35
   34 PTC=1-KK/6
      CD5=CDR(ID,IM)+PU*(CDR(IDD,IM)-CDR(ID,IM))
      CD6=CDR(ID,IMM)+PU*(CDR(IDD,IMM)-CDR(ID,IMM))
      GOTO36
   35 PTC=(KK-6)/2
      CD5=CDT(ID,IM)+PU*(CDT(IDD,IM)-CDT(ID,IM))
      CD6=CDT(ID,IMM)+PU*(CDT(IDD,IMM)-CDT(ID,IMM))
   36 CD3=CD3+PTC*(CD5-CD3)
      CD4=CD4+PTC*(CD6-CD3)
   37 CONTINUE
      CLU=CL3+PM*(CL4-CL3)  $CDU=CD3+PM*(CD4-CD3)
C     CX, CZ COEFF PARRALEL AND PERPINDICULAR TO BLADE TWIST AXIS IN PLANE
C     PERPINDICULAR TO SHAFT AXIS
      CX=(-CLU*SIN(AH)+CDU*COS(AH))*(VX*VX+VY*VY)*SIG/VT**2
      CZ=(CLU*COS(AH)+CDU*SIN(AH))*(VX*VX+VY*VY)*SIG/VT**2
      EA=EC
      IF(EC.GT.1.) EA=AR
      IF(EC.EQ.0.) EA=HR/R
      DCZ=0.
      DCX=0.
      S9=SB
      CDSY=-CX*COS(SB)-CZ*SIN(B7(KJ))*SIN(S9)+DCX*COS(SB)
      CDSC=CX*SIN(SB)-CZ*SIN(B7(KJ))*COS(S9)-DCX*SIN(SB)
      IF(EC.EQ.0.) GOTO23
      GOTO24
   23 EA=EA*SIN(B7(KJ))
      IF(KJ.GT.12.) EA=-EA
   24 CONTINUE
      CMXC=-CZ*COS(B7(KJ))*EA*SIN(SB)
      IF(EC.EQ.0.) GOTO25
      GOTO26
   25 EA=EA*SIN(B7(KJ))
      IF(KJ.GT.7.OR.KJ.LT.19) EA=-EA
   26 CONTINUE
      CMYC=-CZ*COS(B7(KJ))*EA*COS(SB)
      CYS=CYS+CDSY
      CMX=CMX+CMXC  $CMY=CMY+CMYC
      CZ=CZ-DCZ
      CTS=CTS+CZ  $CHS=CHS+CDSC  $CPS=CPS+CX*AR
      CRM=-CZ*COS(B7(KJ))*EA
      CRS=CRS+CRM
      IF(KK-8)106,104,106
  104 CTS=CTS-CZ/2.
      CYS=CYS-CDSY/2.
      CHS=CHS-CDSC/2.  $CPS=CPS-CX/2.
      CMX=CMX-CMXC/2.  $CMY=CMY-CMYC/2.
      CRS=CRS-CRM/2.
  106 CONTINUE
```

```
      AS=AA*57.3
      AL2=FN*AL2
      B1=B1+C7/(G1*AR)-32.2*R/(AR*VT*VT)
      IF(EC.EQ.2.) B1=0.
      IF(JJ-5)19,6,19
    6 CONTINUE
      IF(LK-2)19,20,19
   20 CONTINUE
      IF(KJ.EQ.1) GOTO17
      IF(KJ-7)18,17,18
   18 IF(KJ-19)19,17,19
   17 WRITE(6,4)AS,SY,AL2,CLU,CDU,AR ,STM,BP
   19 CONTINUE
  103 CONTINUE
      CT=CTS/8.              $CH=CHS/8.
      C7=CMX/8.  $C8=CMY/8.
      CMXDS=C7/2. $CMYDS=C8/2.
      CTDS=CT/2.
      CDDS=CH/2.
      CYDS=CYS/16.
      CRY=CRS/16.
      IF(EC.EQ.3.) B1=CRY/CRK
      CQDS=CPS/16.
      BP=B1*57.3/8.
      BQ=B1/8.
      B7(KJ)=BQ
      B1=0.
      SJ=SK*57.3
   15 FORMAT(4X,2HAS,8X,2HTC,8X,2HTB,7X,4HCTDS,6X,4HCDDS,6X,4HCQDS,7X,2H
     1SV)
  105 CTSS=CTSS+CTDS  $CDSS=CDSS+CDDS  $CQSS=CQSS+CQDS
      CMXSS=CMXSS+CMXDS
      CMYSS=CMYSS+CMYDS
      CYSS=CYSS+CYDS
  100 CONTINUE
      IF(EC.EQ.3.) GOTO7
      IF(EC.GT.0.) GOTO5
    7 CONTINUE
      DO 3 KJ=1,12
      KL=KJ+12
      AB=1.
      B7(KJ)=AB*(B7(KJ)-B7(KL))/2.
    3 B7(KL)=-B7(KJ)
    5 CONTINUE
  107 CONTINUE
      CTSS=CTSS/24.  $CDSS=CDSS/24.  $CQSS=CQSS/24.
      CMXSS=CMXSS/24.  $CMYSS=CMYSS/24.  $CYSS=CYSS/24.
       CLSS=CTSS*COS(AA)-CDSS*SIN(AA)
      CHSS=CTSS*SIN(AA)+CDSS*COS(AA)
      CTC=C2(IJ)
      SS=SM*57.3
      ENC=OMU*CTSS/CQSS
      WRITE(6,152)
      WRITE(6,16)
      WRITE(6,2)
      WRITE(6,9)AS,TC,SJ,VT,OMU,CTSS,CDSS,CLSS,CHSS,CQSS,SV,CTC,ENC
      WRITE(6,1)SS,CMXSS,CMYSS,CYSS,BQ,SB,AH
   16 FORMAT(4X,2HAS,5X,2HTC,7X,2HTB,6X,2HVT,4X,3HOMU,5X,4HCTSS,8X,4HCDS
     1S,8X,4HCLSS,7X,4HCHSS, 7X,4HCQSS, 7X,2HSV, 7X,3HCTC,6X,3HENC)
    9 FORMAT(3F8.2,F8.0,F6.3,5F11.6,F11.3,F11.6,F8.3)
```

```
    1 FORMAT(F6.3,6F11.6)
    2 FORMAT(2X,2HSS,5X,5HCMXSS,7X,5HCMYSS,7X,4HCYSS)
      C1(IJ)=CTSS
      J9=JJ-5
      IF(J9.EQ.0)GOTO102
      SMF=SMF-.001
   99 SV=SV+SMF*VT
      SL=(C1(1)-C2(1)-C1(2)+C2(2))/(E3(1)-E3(2))
      E1=(C1(2)-C2(2))/SL
  101 SV=(E3(2)-E1)*VT
  102 WRITE(6,152)
      RETURN
      END
      SUBROUTINE PRNT(UX)
      DIMENSION UX(12,7)
      WRITE(6,21)
    1 FORMAT(5X,24HLAT CYCLIC EFFECTIVENESS)
    2 FORMAT(5X,26HPITCH CYCLIC EFFECTIVENESS)
    3 FORMAT(5X,12HROLL DAMPING)
    4 FORMAT(5X,13HPITCH DAMPING)
    5 FORMAT(5X,16HFORWARD VELOCITY)
    6 FORMAT(5X,17HVERTICAL VELOCITY)
    7 FORMAT(5X,15HANGLE OF ATTACK)
    8 FORMAT(5X,13HSIDE VELOCITY)
    9 FORMAT(5X,8HSIDESLIP)
   10 FORMAT(5X,16HROTOR COLLECTIVE)
   11 FORMAT(5X,11HYAW DAMPING)
   12 FORMAT(5X,21HTAIL ROTOR COLLECTIVE)
   17 FORMAT(8F15.8)
      DO 20 I=1,12
      IF(I.EQ.1) WRITE(6,1)
      IF(I.EQ.2) WRITE(6,2)
      IF(I.EQ.3) WRITE(6,3)
      IF(I.EQ.4) WRITE(6,4)
      IF(I.EQ.5) WRITE(6,5)
      IF(I.EQ.6) WRITE(6,6)
      IF(I.EQ.7) WRITE(6,7)
      IF(I.EQ.8) WRITE(6,8)
      IF(I.EQ.9) WRITE(6,9)
      IF(I.EQ.10)WRITE(6,10)
      IF(I.EQ.11)WRITE(6,11)
      IF(I.EQ.12)WRITE(6,12)
   20 WRITE(6,17)(UX(I,7),(UX(I,J),J=1,6))
   21 FORMAT(/)
      WRITE(6,21)
      RETURN
      END
*     LIST(STOP)
      LIST
*     DATA
```

0.	.21	.42	.63	.85	1.06	1.27	1.32	1.02
.9	.81	.8	.82	.88	.95	1.02	1.05	1.08
1.09	1.09	1.09	1.08	1.06	1.03	1.0	.96	.92
.88	.84	.80	.78	.73	.68	.63	.58	.53
.48	.43	.38	.33	.28	.23	.17	.13	.06

0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.008	.008	.0085	.009	.01	.0125	.017	.038	.16	
.22	.28	.33	.4	.45	.52	.54	.56	.58	
.60	.62	.64	.66	.68	.70	.72	.74	.76	
.78	.82	.84	.86	.88	.90	.92	.94	.96	
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10
.008									D11
.008	.006	.0085	.009	.01	.0125	.017	.038	.16	D21
.22	.28	.33	.4	.45	.52	.54	.56	.58	D22
.008	.008	.0085	.009	.01	.0125	.017	.038	.16	D21
.22	.28	.33	.4	.45	.52	.54	.56	.58	D22
0.	.23	.46	.69	.92	1.08	1.12	1.08	.92	L41
.9	.81	.8	.82	.88	.95	1.02	1.05	1.08	L42
1.09	1.09	1.09	1.08	1.06	1.03	1.	.96	.92	L43
.88	.84	.8	.78	.73	.68	.63	.58	.53	L44
.48	.43	.38	.33	.28	.23	.17	.13	.06	L5
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.008	.006	.0085	.01	.015	.023	.058	.15	.21	D41
.26	.31	.42	.48	.52	.53	.54	.56	.58	D42
.6	.62	.64	.66	.68	.7	.72	.74	.76	D43
.78	.82	.84	.66	.88	.9	.92	.94	.96	D44
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10
.006									D11
.008	.008	.0085	.01	.015	.023	.058	.15	.21	D41
.26	.31	.42	.48	.52	.53	.54	.56	.58	D42
.008	.008	.0085	.01	.015	.023	.058	.15	.21	D41
.26	.31	.42	.48	.52	.53	.54	.56	.58	D42
0.	.27	.54	.75	.86	.91	.93	.96	.98	L61
[illegible]	.85	.86	.95	1.02	1.12	1.14	1.11	1.08	L62
1.09	1.09	1.09	1.08	1.06	1.03	1.	.96	.92	L63
.88	.84	.88	.78	.73	.68	.63	.58	.53	L64
.48	.43	.38	.33	.28	.23	.17	.13	.06	L5
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.008	.008	.0092	.019	.05	.10	.19	.24	.29	D61
.35	.41	.48	.55	.55	.53	.54	.56	.58	D62

78	.82	.84	.86	.88	.9	.92	.94
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02
.98	.96	.94	.92	.90	.88	.86	.84
.80	.78	.76	.74	.72	.70	.68	.66
.62	.60	.58	.56	.52	.45	.40	.33
.22	.16	.038	.017	.0125	.01	.009	.0085
.008							
.008	.008	.0092	.019	.05	.10	.19	.24
5	341	.48	.55	.55	.53	.54	.56
.008	.008	.0092	.019	.05	.10	.19	.24
5	341	.48	.55	.55	.53	.54	.56
0.	.39	.61	.68	.70	.72	.74	.75
.77	.78	.79	.80	.8	.8	.8	.8
.8	.8	.8	.8	.8	.8	.8	.8
.8	.8	.8	.78	.73	.68	.63	.58
.48	.43	.38	.33	.28	.23	.17	.13
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33
-.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67
-.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46
0.							
.019	.038	.08	.12	.16	.19	.22	.28
.37	.42	.5	.55	.55	.53	.54	.56
6	.62	.64	.66	.68	.7	.72	.74
78	.82	.84	.86	.88	.9	.92	.94
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02
.98	.96	.94	.92	.90	.88	.86	.84
.80	.78	.76	.74	.72	.70	.68	.66
.62	.60	.58	.56	.52	.45	.40	.33
.22	.16	.038	.017	.0125	.01	.009	.0085
.008							
.019	.038	.08	.12	.16	.19	.22	.28
.37	.42	.5	.55	.55	.53	.54	.56
.019	.038	.08	.12	.16	.19	.22	.28
.37	.42	.5	.55	.55	.53	.54	.56
0.	.2	.4	.56	.58	.59	.60	.60
.67	.7	.78	.82	.88	.95	1.02	1.05
1.09	1.09	1.09	1.08	1.06	1.03	1.	.96
.88	.84	.8	.78	.73	.68	.63	.58
.48	.43	.38	.33	.28	.23	.17	.13
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33
-.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67
-.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46
0.							
.15	.17	.19	.23	.27	.3	.33	.35
.4	.42	.5	.55	.55	.53	.54	.56
5	.62	.64	.66	.68	.7	.72	.74
.78	.82	.84	.86	.88	.9	.92	.94
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02
.98	.96	.94	.92	.90	.88	.86	.84
.80	.78	.76	.74	.72	.70	.68	.66
.62	.60	.58	.56	.52	.45	.40	.33
.22	.16	.038	.017	.0125	.01	.009	.0085

.6	.62	.64	.66	.68	.7	.72	.74	.76	D63
78	.82	.84	.86	.88	.9	.92	.94	.96	D64
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10
.008									D11
.008	.008	.0092	.019	.05	.10	.19	.24	.29	D61
5	341	.48	.55	.55	.53	.54	.56	.58	D62
.008	.008	.0092	.019	.05	.10	.19	.24	.29	D61
5	341	.48	.55	.55	.53	.54	.56	.58	D62
0.	.39	.61	.68	.70	.72	.74	.75	.76	L81
.77	.78	.79	.80	.8	.8	.8	.8	.8	L82
.8	.8	.8	.8	.8	.8	.8	.8	.8	L83
.8	.8	.8	.78	.73	.68	.63	.58	.53	L84
.48	.43	.38	.33	.28	.23	.17	.13	.06	L5
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
-.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
-.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.019	.038	.08	.12	.16	.19	.22	.28	.32	D81
.37	.42	.5	.55	.55	.53	.54	.56	.58	D82
6	.62	.64	.66	.68	.7	.72	.74	.76	D83
78	.82	.84	.86	.88	.9	.92	.94	.96	D84
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10
.008									D11
.019	.038	.08	.12	.16	.19	.22	.28	.32	D81
.37	.42	.5	.55	.55	.53	.54	.56	.58	D82
.019	.038	.08	.12	.16	.19	.22	.28	.32	D81
.37	.42	.5	.55	.55	.53	.54	.56	. 8	D82
0.	.2	.4	.56	.58	.59	.60	.60	.62	L101
.67	.7	.78	.82	.88	.95	1.02	1.05	1.08	L102
1.09	1.09	1.09	1.08	1.06	1.03	1.	.96	.92	L103
.88	.84	.8	.78	.73	.68	.63	.58	.53	L104
.48	.43	.38	.33	.28	.23	.17	.13	.06	L5
0.	-.05	-.1	-.15	-.2	-.25	-.29	-.33	-.37	L6
-.41	-.45	-.49	-.53	-.57	-.61	-.64	-.67	-.70	L7
-.73	-.75	-.77	-.78	-.79	-.80	-.81	-.82	-.82	L8
-.82	-.81	-.80	-.79	-.77	-.71	-.63	-.55	-.47	L9
-.45	-.48	-.54	-.57	-.59	-.59	-.53	-.46	-.21	L10
0.									L11
.15	.17	.19	.23	.27	.3	.33	.35	.38	D101
.4	.42	.5	.55	.55	.53	.54	.56	.58	D102
6	.62	.64	.66	.68	.7	.72	.74	.76	D103
.78	.82	.84	.86	.88	.9	.92	.94	.96	D104
.98	1.	1.02	1.04	1.06	1.08	1.1	1.2	1.22	D5
1.24	1.22	1.2	1.1	1.08	1.06	1.04	1.02	1.	D6
.98	.96	.94	.92	.90	.88	.86	.84	.82	D7
.80	.78	.76	.74	.72	.70	.68	.66	.64	D8
.62	.60	.58	.56	.52	.45	.40	.33	.28	D9
.22	.16	.038	.017	.0125	.01	.009	.0085	.008	D10

.008									D11
15	.17	.19	.23	.27	.3	.33	.35	.38	D101
.	.42	.5	.55	.55	.53	.54	.56	.58	D102
.15	.17	.19	.23	.27	.3	.33	.35	.38	D101
.4	.42	.5	.55	.55	.53	.54	.56	.58	D102
7.	0.	745.	.0651	-.1	0.	2.	22.	.00222	
-3.	-.5	6.	27.	745.	.105	4.3	18.5	10.9	
600.	24.	0.							
7.	0.	745.	.0651	-.1	0.	2.	22.	.00222	
-3.	0.	6.	27.	745.	.105	4.3	18.5	10.9	
600.	24.	2.							
7.	0.	745.	.0651	-.1	0.	2.	22.	.00222	
-3.	0.	6.	27.	745.	.105	4.3	18.5	10.9	
600.	24.	.15							

PROB

End Airfoil Data

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APPENDIX B

PROGRAM FOR SOLUTION OF LONGITUDINAL EQUATIONS

TABLE B.1

EXPANSION OF LONGITUDINAL DETERMINANT

$$
\begin{array}{ccc}
\underline{\mu} & \underline{\alpha} & \underline{\theta} \\
C_{x_\mu} - \frac{m'}{V}s & C_{x_\alpha} & -C_L \\
C_{Z_\mu} & C_{Z_\alpha} + (C_{Z_{\dot\alpha}} - m)s & +(C_{Z_{\dot\theta}} + m')s \\
C_{m_\mu} & C_{m_\alpha} + C_{m_{\dot\alpha}}s & C_{m_{\dot\theta}}s \quad -Iys^2
\end{array}
$$

	$A's^4$	$B's^3$	$C's^2$	$D's$	E'
BASE VALUES	$-\frac{m'^2}{V}Iy'$	$-C_{Z_{\dot\alpha}}C_{x_\mu}Iy'$	$C_{Z_\mu}C_{x_\alpha}Iy'$	$C_{x_\alpha}C_{m_\mu}C_{Z_{\dot\theta}}$	$-C_{Z_\mu}C_LC_{m_\alpha}$
	$\frac{m'}{V}C_{Z_{\dot\alpha}}Iy'$	$C_{x_\mu}m'Iy'$	$-C_{x_\mu}C_{Z_\alpha}Iy'$	$C_{x_\alpha}C_{m_\mu}m'$	$C_{m_\mu}C_LC_{Z_\alpha}$
		$\frac{m'}{V}C_{m_{\dot\theta}}$	$C_{Z_{\dot\alpha}}C_{x_\mu}C_{m_{\dot\theta}}$	$-C_LC_{Z_\mu}C_{m_{\dot\alpha}}$	
		$\frac{m'}{V}C_{Z_\alpha}Iy'$	$-C_{x_\mu}C_{m_{\dot\theta}}m'$	$C_{m_\mu}C_LC_{Z_{\dot\alpha}}$	
		$-\frac{m'}{V}C_{Z_\alpha}C_{m_{\dot\theta}}$	$-\frac{m'}{V}C_{Z_\alpha}C_{m_{\dot\theta}}$	$-C_{m_\mu}C_Lm'$	
		$\frac{m'}{V}C_{m_{\dot\alpha}}C_{Z_{\dot\theta}}$	$-C_{x_\mu}C_{m_{\dot\alpha}}C_{Z_{\dot\theta}}$	$-C_{Z_\mu}C_{x_\alpha}C_{m_{\dot\theta}}$	
		$\frac{m'^2}{V}C_{m_{\dot\alpha}}$	$-C_{x_\mu}C_{m_{\dot\alpha}}m'$	$-C_{m_\alpha}C_{x_\mu}C_{Z_{\dot\theta}}$	
			$\frac{m'}{V}C_{m_\alpha}C_{Z_{\dot\theta}}$	$-C_{m_\alpha}C_{x_\mu}m'$	
			$\frac{m'^2}{V}C_{m_\alpha}$		

TABLE B.1 (Continued)
EXPANSION OF LONGITUDINAL DETERMINANT
PITCH CONTROLLER TERMS

	A's[4]	B's[3]	C's[2]	D's	E'	
θ SAS CONTRIBUTIONS			$\frac{m'^2}{v} C_{m_{B1}}$	$C_{Z_{\dot\alpha}} C_{x_\mu} C_{m_{B1}}$	$C_{x_\alpha} C_{m_\mu} C_{Z_{B1}}$	
			$\frac{m'}{v} C_{m_{\dot\alpha}} C_{Z_{B1}}$	$-C_{x_\mu} m' C_{m_{B1}}$	$-C_{Z_\mu} C_{x_\alpha} C_{m_{B1}}$	
	Gain C52		$-\frac{m'}{v} C_{Z_{\dot\alpha}} C_{m_{B1}}$	$-\frac{m'}{v} C_{Z_\alpha} C_{m_{B1}}$	$C_{Z_\alpha} C_{x_\mu} C_{m_{B1}}$	
				$-C_{x_\mu} C_{m_\alpha} C_{Z_{B1}}$	$-C_{m_\alpha} C_{x_\mu} C_{Z_{B1}}$	$\frac{dB_1}{d\theta}$
				$\frac{m'}{v} C_{m_\alpha} C_{Z_{B1}}$	$-C_{Z_\mu} C_{m_\alpha} C_{x_{B1}}$	
				$-C_{Z_\mu} C_{m_{\dot\alpha}} C_{x_{B1}}$	$C_{m_\mu} C_{Z_\alpha} C_{x_{B1}}$	
				$C_{m_\mu} C_{Z_{\dot\alpha}} C_{x_{B1}}$		
				$-C_{m_\mu} m' C_{x_{B1}}$		
			3*	2	1	
	C_{51}	3	2	1		$\frac{dB_1}{d\dot\theta}$
	C_{50} 3	2	1			$\frac{dB_1}{d\ddot\theta}$

*Note triangular relationship between

θ $\dot\theta$ $\ddot\theta$ SAS Contribution

TABLE B.1

EXPANSION OF LONGITUDINAL DETERMINANT
(Continued)

α SAS CONTRIBUTIONS	GAINS	A's[4]	B's[3]	C's[2]	D's	E'	
	C_{15}		$\frac{m'}{V} Iy' C_{Z_{B1}}$ 4	$-C_{x_\mu} Iy' C_{Z_B 1}$ $\frac{m'}{V} C_{m_{\dot\theta}} C_{Z_{B1}}$ $\frac{m'}{V} C_{Z_{\dot\theta}} C_{m_{B1}}$ $\frac{m'^2}{V} C_{m_{B1}}$ 3	$C_{x_\mu} C_{m_{\dot\theta}} C_{Z_{B1}}$ 1 $-C_{x_\mu} C_{Z_{\dot\theta}} C_{m_{B1}}$ $- m' C_{x_\mu} C_{m_{B1}}$ 2	$-C_{Z_\mu} C_L C_{m_{B1}}$ $C_{m_\mu} C_L C_{Z_{B1}}$ 1	$\frac{dB_1}{d\alpha}$
	C_{16}	4	3	2	1		$\frac{dB_1}{d\dot\alpha}$
	C_{17}	3	2	1			$\frac{dB_1}{d\ddot\alpha}$

* Note triangular relationship between

α $\dot\alpha$ $\ddot\alpha$ (1) SAS Contribution

(1) Quintic

```
      LIST(START)
C                      SOLUTION OF LONGITUDINAL EQUATIONS
C
C
C        THIS PROGRAM EVALUATES THE LONGITUDINAL STABILITY QUARTIC
C     COEFFICIENTS A,B,C,D,E  OBTAINS THE RESULTING ROOTS,PERIOD
C     AND TIME TO DAMP TO HALF AMPLITUDE.  TO OBTAIN SATISFACTORY
C     STABILITY AUTOPILOT GAINS C50=B1/TDD,C51=B1/TD, AND C50=B1/THETA
C     MAY BE USED.
C        THE REQUIRED INPUT CARDS AND PROPER COLUMNS ALONG WITH THE SYMBOLS
C     AND IDENTIFICATION ARE PRESENTED BELOW.
C   CARD  COLUMN  SYMBOL
C    1     1-15   PM         MASS M*V/Q*AD
C    1    16-30   V          VELOCITY              FT/SEC
C    1    31-45   CL1        LIFT COEFFICIENT   W/Q*AD    AD DISC AREA
C    1    46-60   ALPH       ANGLE OF ATTACK
C    1    61-75   YI         MOMENT OF INERTIA  IYY/Q*AD*ROTR
C    2     1-15   CXU        STABILITY DERIVATIVE  DCX/DU
C    2    16-30   CXA                              DCX/DALPHA
C    2    31-45   CZU
C    2    46-60   CZA
C    2    61-75   CZAD
C    3     1-15   CZTD
C    3    16-30   CMU              FOR STABILITY DERIVATIVES SEE HELIO 4
C    3    31-45   CMA1
C    3    61-75   CMTD1
C    4     1-15   CZTC             COLLECTIVE PITCH  CONTROL EFFECT
C    4    16-30   CMTC             COLLECTIVE PITCH
C    4    31-45   CZB1             CYCLIC PITCH
C    4    46-60   CMB1             CYCLIC PITCH
C    4    61-75   CMI              HORIZONTAL TAIL
C    4A    1-15   CXI
C    5     1-15   FM             AUTOPILOT GAIN
C          1 -30  GV             AUTOPILOT GAIN
C    5    31-45   C50            AUTOPILOT COEFFICIENT S2
C    5    46-60   C51
C    5   460-75   C52
C    6     1-10   MORE=1 NEW GAINS, -1 NEW SET, 0 END
C
C                       TYPICAL INPUTS ARE
C,000194           1.              .0062             0.               .00051
C-.0000042         .0000079        -.000009          -.000043         0.
C0.                .000000078      .000000008        0.               .00000022
C--.041             .00000336       0.                -.0013           0.
C,0045
C0.         0.          0.          0.          0.
C1
C1.         1.          1.          2.          4.
C-1
C1.26              100.            .405              0.               .033
C.000486           .05207          -.000173          -.793            0.
C0,                .00035          -.0427            -.00088          -.13
C-3.14             .155            .793              -.168            -.0144
C.353
C0.         0.          0.          0.          0.
C0
C      PROB
      DIMENSION XCOF(11),COF(11),ROOTR(10),ROOTI(10)
```

```
      COMMONXCOF,COF,M,ROOTR,ROOTI,IER
      M=4
   98 CONTINUE
      READ(5,6)PM,V,CL1,ALPH,YI
      READ(5,6)CXU,CXA,CZU,CZA,CZAD
      READ(5,6)CZTD1,CMU,CMA1,CMAD,CMTD1
      READ(5,6)CZTC,CMTC,CZB1,CMB1,CMI
      READ(5,6)CXI
    1 FORMAT(7F10.6)
      WRITE(6,2)
    2 FORMAT(5X,48HAIRCRAFT GA INPUTS IN ORDER ARE PM,V,CL1,ALPH,YI)
      WRITE(6,6)PM,V,CL1,ALPH,YI
      WRITE(6,3)
    3 FORMAT(2X,74HCXU,CXA,CZU,CZA,CZAD,CZTD1,CMU,CMA1,CMAD,CMTD1,CZTC,C
     1MTC,CZB1,CMB1,CMI,CXI)
      WRITE(6,6)CXU,CXA,CZU,CZA,CZAD
      WRITE(6,6)CZTD1,CMU,CMA1,CMAD,CMTD1
      WRITE(6,6)CZTC,CMTC,CZB1,CMB1,CMI
      WRITE(6,6)CXI
      CMI=CMB1+CMI
      CZI=CZB1
      YI1=YI
   97 CONTINUE
      READ(5,1)FM,GV,C50,C51,C52
      WRITE(6,1)FM,GV,C50,C51,C52
      FG=FM*GV
      YI=YI1-FG*CMI*C50
      C12=FG*C52
      C13=FG*C51
      C14=0.
      C15=FG*C50
      A=CXU
      B=CZU
      CMTD=CMTD1+C13*CMI
      CZTD=CZTD1+C13*CZI
      C=CXA
C     WHEN V=0 PM=M/Q*AD  Q=RHO*VTIP*VTIP  USE CZW ETC.
      IF(V-1.)9,9,8
    8 F=CZTD+PM
      GOTO10
    9 F=CZTD
   10 CONTINUE
      D=CZAD-PM
      E=CZA+C14*CZI
      CMA=CMA1+C14*CMI
      A1=PM*D*YI/V
      B1=-(A*D*YI)-PM*D*CMTD/V+PM*YI*E/V+PM*F*CMAD/V
      C1=A*D*CMTD-A*E*YI-PM*E*CMTD/V+PM*F*CMA/V-A*F*CMAD
      C1=C1+B*C*YI+C12*PM*(CZI*CMAD-CMI*D)/V
      D1=A*E*CMTD-A*F*CMA+C*F*CMU
      D1=D1-B*C*CMTD-B*CL1*CMAD
      D1=D1+D*CL1*CMU
      D1=D1+C12*PM*(CMA*CZI-E*CMI)/V+C12*A*(D*CMI-CMAD*CZI)
      E1=-(B*CMA*CL1)+E*G 1*CMU
      E1=E1+C12*A*(E*CMI-CMA*CZI)+C12*C*(CMU*CZI-B*CMI)
      C90=CZA*CMU-CZY*CMA
      C91=D*CMU-CZU*CMAD
      E1=E1+C12*CXI*C90
      D1=D1+C12*CXI*C91
      C1=C1+C13*CXI*C91
```

```
      D1=D1+C13*CXI*C90
      A1=A1+C15*CZI*CMAD*PM/V-C15*CMI*D*PM/V
      B1=B1+C15*CZI*((PM/V)*CMA-CXU*CMAD)+C15*CMI*(CXU*D-CZA*PM/V)+C15*C
     1XI*C91
      C1=C1+C15*CZI*(CMU*CXA-CMA*CXU)+C15*CMI*(CXU*CZA-CZU*CXA)+C15*CXI*
     1C90
      A2=1.
      B2=B1/A1
      C2=C1/A1
      D2=D1/A1
      E2=E1/A1
      XCOF(1)=E2
      XCOF(2)=D2
      XCOF(3)=C2
      XCOF(4)=B2
      XCOF(5)=A2
    5 FORMAT(2X,43HQUARTIC COEFFICIENTS ARE IN ORDER A,B,C,D,E)
      WRITE(6,5)
      WRITE(6,6)A,B,C,D,E
      WRITE(6,6)A1,B1,C1,D1,E1
      WRITE(6,6)A2,B2,C2,D2,E2
    6 FORMAT(5E15.8)
      WRITE(6,1)C12,C13,C14
      CALL ROLRT(XCOF,COF,M,ROOTR,ROOTI,IER)
      WRITE(6,7)
    7 FORMAT(8X,9HREAL ROOT,8X,10HIMAG. ROOT,8X,6HPERIOD,9X,12HTIME TO H
     1ALF)
      DO20I=1,4
      IF(ROOTI(I))81,80,81
   80 P=200000.
      GOTO82
   81 P=2.*3.14/ROOTI(I)
   82 D=.69/ROOTR(I)
   20 WRITE(6,11)ROOTR(I),ROOTI(I),P,D
      READ(5,29)MORE
   29 FORMAT(I5)
      IF(MORE)98,30,97
   30 IER=2
   11 FORMAT(5X,6E17.8)
      END
      SUBROUTINE ROLRT(XCOF,COF,M,ROOTR,ROOTI,IER)
      DIMENSION XCOF(10),COF(10),ROOTR(10),ROOTI(10)
      IFIT=0
      N=M
      IER=0
      IF(XCOF(N+1))10,25,10
   10 IF(N)15,15,32
   15 IER=1
   20 RETURN
   25 IER=4
      GOTO20
   30 IER=0
      GOTO20
   32 IF(N-36)35,35,30
   35 NX=N
      NXX=N+1
      N2=1
      KJ1=N+1
      DO40L=1,KJ1
      MT=KJ1-L+1
```

```
40 COF(MT)=XCOF(L)
45 XO=.00500101
   YO=.01000101
   IN=0
50 X=XO
   XO=-10.*YO
   YO=-10.*X
   X=XO
   Y=YO
   IN=IN+1
   GOTO59
55 IFIT=1
   XPR=X
   YPR=Y
59 ICT=0
60 UX=0.
   UY=0.
   V=0.
   YT=0.
   XT=1.
   U=COF(N+1)
   IF(U)65,130,65
65 DO70I=1,N
   L=N-I+1
   XT2=X*XT-Y*YT
   YT2=X*YT+Y*XT
   U=U+COF(L)*XT2
   V=V+COF(L)*YT2
   FI=I
   UY=UY-FI*YT*COF(L)
   UX=UX+FI*XT*COF(L)
   XT=XT2
70 YT=YT2
   SUMSQ=UX*UX+UY*UY
   IF(SUMSQ)75,110,75
75 DX=(V*UY-U*UX)/SUMSQ
   X=X+DX
   DY=-(U*UY+V*UX)/SUMSQ
   Y=Y+DY
78 IF(ABS(DY)+ABS(DX)-.00001)100,80,80
80 ICT=ICT+1
   IF(ICT-500)60,85,85
85 IF(IFIT)100,90,100
90 IF(IN-5)50,95,95
95 IER=3
   GOTO20
100 DO105L=1,NXX
   MT=KJ1-L+1
   TEMP=XCOF(MT)
   XCOF(MT)=COF(L)
105 COF(L)=TEMP
   ITEMP=N
   N=NX
   NX=ITEMP
   IF(IFIT)120,55,120
110 IF(IFIT)115,50,115
115 X=XPR
   Y=YPR
120 IFIT=0
122 IF(ABS(Y/X)-0.00001)135,125,125
```

```
  125 ALPHA=X+X
      SUMSQ=X*X+Y*Y
      N=N-2
      GOTO140
  130 X=0
      NX=NX
      NXX=NXX-1
  135 Y=0
      SUMSQ=0.
      ALPHA=X
      N=N-1
  140 COF(2)=COF(2)+ALPHA*COF(1)
      IF(N-2)147,146,146
  147 NN=2
      GOTO145
  146 NN=N
  145 DO150L=2,NN
      M11=L+1
  150 COF(M11)=COF(M11)+ALPHA*COF(L)-SUMSQ*COF(L-1)
  155 ROOTI(N2)=Y
      ROOTR(N2)=X
      N2=N2+1
      IF(SUMSQ)160,165,160
  160 Y=-Y
      SUMSQ=0.
      GOTO155
  165 IF(N)20,20,45
      RETURN
      END
*     LIST(STOP)
      LIST
*     DATA
.000194        1.              .0062           0.              .00051
-.0000042      .0000079        -.000009        -.000043        0.
0.             .000000078      .000000008      0.              .00000022
-.041          .00000336       0.              -.0013          0.
.0045
0.       0.       0.       0.       0.
1
1.       1.       1.       2.       4.
-1
1.26           100.            .405            0.              .033
.000486        .05207          -.000173        -.793           0.
0.             .00035          -.0427          -.00088         -.13
-3.14          .155            .793            -.168           -.0144
.353
0.       0.       0.       0.       0.
0
      PROB
```


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APPENDIX C

LONGITUDINAL T[illegible]IENT MOTION PROGRAM

```
*      C. _
$      MAXO(2400)
*      LIST(START)
C                            LONGITUDINAL MOTION
C
C      VARIABLE FWD LOOP GAINS LIMIT GVU GVL CORRESPOND TO RTU UPPER
C      FEEDBACK GAINS C50(S2) C51(S) C52
C
C    1      1-15    PM       MASS M*V/Q*AD
C    1     16-30    V        VELOCITY             FT/SEC
C    1     31-45    CL1      LIFT COEFFICIENT     W/Q*AD    AD DISC AREA
C    1     46-60    ALPH     ANGLE OF ATTACK
C    1     61-75    YI       MOMENT OF INERTIA  IYY/Q*AD*ROTR
C    2      1-15    CXU      STABILITY DERIVATIVE   DCX/DU
C    2     16-30    CXA                             DCX/DALPHA
C    2     31-45    CZU
C    2     46-60    CZA
C    2     61-75    CZAD
C    3      1-15    CZTD
C    3     16-30    CMU            FOR STABILITY DERIVATIVES SEE HELIO 4
C    3     31-45    CMA1
C    3     61-75    CMTD1
C    4      1-15    CZTC           COLLECTIVE PITCH  CONTROL EFFECT
C    4     16-30    CMTC           COLLECTIVE PITCH
C    4     31-45    CZB1           CYCLIC PITCH
C    4     46-60    CMB1           CYCLIC PITCH
C    4     61-75    CMI            HORIZONTAL TAIL EFFECTIVENESS
C    4A     1-15    CXI
C    5     01-10    RTU            PITCH CYCLIC VARIABLE GAIN
C    5     16-30    RTL
C    5     21-30    GVU
C    5     31-40    GVL
C    6     01-10    FM             AUTOPILOT GAINS
C    6     11-20    C50
C    6     21-30    C51
C    6     31-40    C52
C    6     41-50    SG       0 END,-1 NEW PM, 1 NEW GAIN
C
C                       LONGITUDINAL EQUATIONS
C   FWD VEL)     ALPHA              THETA
C     XU*U       XA*A              -CL*T          =MU*UD
C     ZU*U       ZA*A+ZAD*AD        ZTD*TD        =M*(WD-V*TD)
C     MU*U       MA*A+MAD*AD        MTD*TD        =IYY*TDD
C                       DETERMINANT IN FORWARD FLIGHT
C   FWD VEL,            ANGLE OF ATTACK      PITCH
C    CXU-(PM/V)*S       CXA                  -CL                  PM=M*V/(Q*AD)
C    CZU                CZA +(CZAD-PM)*S     (CZTD+PM)*S          YI=IYY/(Q*AD*R)
C    CMU                CMA +CMAD*S          CMTD*S +YI*S*S       ALPHA=W/V
C
C                       DETERMINANT FOR HOVER V=0
C   FWD VEL,            VERTICAL VEL,        PITCH
C    CXU-PM*S           CXU                   CL                  PM=M/(Q*AD)
C    CZU                CZW +(CZWD PM)*S     CZTD*S
C    CMU                CMW +CMWD*S          CMTD*S-YI*S*S
C
   97 CONTINUE
      READ(5,7)PM,V,CL1,ALPH,YI
      READ(5,7)CXU,CXA,CZU,CZA,CZAD
      READ(5,7)CZTD1,CMU,CMA1,CMAD,CMTD1
```

```
      READ(5,7)CZTC,CMTC,CZB1,CMB1,CMI
      READ(5,7)CXI
    7 FORMAT(5E15.8)
    1 FORMAT(7F10.6)
      WRITE(6,100)
  100 FORMAT(5X,48HAIRCRAFT GA INPUTS IN ORDER ARE PM,V,CL1,ALPH,YI)
      WRITE(6,7)PM,V,CL1,ALPH,YI
      WRITE(6,101)
  101 FORMAT(2X,74HCXU,CXA,CZU,CZA,CZAD,CZTD1,CMU,CMA1,CMAD,CMTD1,CZTC,C
     1MTC,CZB1,CMB1,CMI,CXI)
      WRITE(6,7)CXU,CXA,CZU,CZA,CZAD
      WRITE(6,7)CZTD1,CMU,CMA1,CMAD,CMTD1
      WRITE(6,7)CZTC,CMTC,CZB1,CMB1,CMI
      WRITE(6,7)CXI
      CZTD=CZTD1
      CMA=CMA1
      CMTD=CMTD1
      CMDE=CMB1+CMI
      CZDE=CZB1
      TV=0.
      V9=V
   98 READ(5,1)RTJ,RTL,GVJ,GVL
      READ(5,1)FM,C50,C51,C52,SG
      WRITE(6,102)RTU,RTL,GVU,GVL
  102 FORMAT(5X,4HRTU=,F9.3,1X,4HRTL=,F9.3,1X,4HGVU=,F9.3,1X,4HGVL=,F9.3
     1)
      WRITE(6,103)FM,C50,C51,C52
  103 FORMAT(5X,3HFM=,F9.4,1X,4HC50=,F9.4,1X,4HC51=,F9.4,1X,4HC52=,F9.4)
      V=V9
      DD1=0.
      TDD2=0.
      GV=0.
      DD2=0.
      THO=0.
      THD=0.
      ALD=0.
      VD=0.
      TM=0.
      DTM=.05
      CD=0.
      DL=DTM/2.
      DEMX=1./57.3
      N=0
      TH=THO
      AO=TH
      VO=V
      AL=AO
C     WHEN V=0 PM=M/Q*AD  Q=RHO*VTIP*VTIP  USE CZW ETC.
      IF(VO)8,9,8
    8 F10=VO/PM
      GOTO10
    9 F10=1./PM
   10 CONTINUE
      F11=PM-CZAD
      DO 80 I=1,800
      CD1=CD
      IF(TM-.5)70,71,72
   70 CD=TM/.5
      GOTO 75
   71 CD=1.
```

```
      GOTO 75
   72 IF(TM-1.)73,74,74
   73 CD=(1.-TM)/.5
      GOTO 75
   74 CD=0.
   75 DE=CD1*DEMX
      DA=AL-AO
      DV=V-VO
      DTH=TH-THO
      RT=ABS((DD2-DD1)/DTM)
      IF(RT-RTU)201,200,200
  200 GV=GVU
      GOTO 204
  201 IF(RT-RTL)202,202,203
  202 GV=GVL
      GOTO 204
  203 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
  204 CONTINUE
      IF(TM-1.)350,350,351
  350 GV=0.
  351 CONTINUE
      FG=FM*GV
      VD1=(CXU*DV+CXA*DA-CL1*DTH+FG*CXI*(C50*TDD2+C51*THD+
      ALD1=(CZU*DV+CZA*DA+(CZTD+PM+C51*FG*CZDE)*THD+C52*FG
     1*(DE+C50*TDD2*FG))/F11
      TDD1=(CMU*DV+CMA*DA+CMAD*ALD1+(CMTD+C51*FG*CMDE)*THD
     1FG*TH)+TV)/(YI-C50*FG*CMDE)
      DD1=FM*GV*(C50*TDD2+C51*THD+C52*TH)
      DD15=ABS(DD1)
      IF(DD15-.26)41,40,40
   40 DD1=.26*DD1/DD15
      VD1=(CXU*DV+CXA*DA-CL1*DTH+CXI*(DD1+DE))*F10
      ALD1=(CZU*DV+CZA*DA+CZTD*THD+CZDE*(DD1+DE))/F11
      TDD1=(CMU*DV+CMA*DA+CMTD*THD+CMDE*(DD1+DE))/YI
   41 CONTINUE
      V1=V+VD1*DL
      AL1=AL+ALD1*DL
      TD1=THD*TDD1*DL
      T1=TH+THD*DL+.5*TDD1*DL*DL
      V2=V1+VD1*DL
      AL2=AL1+ALD1*DL
      TD2=TD1+TDD1*DL
      T2=T1+THD*DL+.5*TDD1*DL*DL
      DA=AL2-AO
      DV=V2-VO
      DTH=T2-THO
      DE=CD*DEMX
      DD1=FM*GV*(C50*TDD1+C51*TD1+ 52*T1)
      RT=ABS((DD1-DD2)/DTM)
      IF(RT-RTU)301,300,300
  300 GV=GVU
      GOTO 304
  301 IF(RT-RTL)302,302,303
  302 GV=GVL
      GOTO 304
  303 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
  304 CONTINUE
      IF(TM-1.)2,2,6
    2 GV=0.
    6 CONTINUE
```

```
      GOTO 75
   72 IF(TM-1.)73,74,74
   73 CD=(1.-TM)/.5
      GOTO 75
   74 CD=0.
   75 DE=CD1*DEMX
      DA=AL-AO
      DV=V-VO
      DTH=TH-THO
      RT=ABS((DD2-DD1)/DTM)
      IF(RT-RTU)201,200,200
  200 GV=GVU
      GOTO 204
  201 IF(RT-RTL)202,202,203
  202 GV=GVL
      GOTO 204
  203 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
  204 CONTINUE
      IF(TM-1.)350,350,351
  350 GV=0.
  351 CONTINUE
      FG=FM*GV
      VD1=(CXU*DV+CXA*DA-CL1*DTH+FG*CXI*(C50*TDD2+C51*THD+C52* TH))*F10
      ALD1=(CZU*DV+CZA*DA+(CZTD+PM+C51*FG*CZDF)*THD+C52*FG*CZDE*TH +CZDE
     1*(DE+C50*TDD2*FG))/F11
      TDD1=(CMU*DV+CMA*DA+CMAD*ALD1+(CMTD+C51*FG*CMDE)*THD+CMDE*(DE+C52*
     1FG*TH)+TV)/(YI-C50*FG*CMDE)
      DD1=FM*GV*(C50*TDD2+C51*THD+C52*TH)
      DD15=ABS(DD1)
      IF(DD15-.26)41,40,40
   40 DD1=.26*DD1/DD15
      VD1=(CXU*DV+CXA*DA-CL1*DTH+CXI*(DD1+DE))*F10
      ALD1=(CZU*DV+CZA*DA+CZTD*THD+CZDE*(DD1+DE))/F11
      TDD1=(CMU*DV+CMA*DA+CMTD*THD+CMDE*(DD1+DE))/YI
   41 CONTINUE
      V1=V+VD1*DL
      AL1=AL+ALD1*DL
      TD1=THD*TDD1*DL
      T1=TH+THD*DL+.5*TDD1*DL*DL
      V2=V1+VD1*DL
      AL2=AL1+ALD1*DL
      TD2=TD1+TDD1*DL
      T2=T1+THD*DL+.5*TDD1*DL*DL
      DA=AL2-AO
      DV=V2-VO
      DTH=T2-THO
      DE=CD*DEMX
      DD1=FM*GV*(C50*TDD1+C51*TD1+ 52*T1)
      RT=ABS((DD1-DD2)/DTM)
      IF(RT-RTU)301,300,300
  300 GV=GVU
      GOTO 304
  301 IF(RT-RTL)302,302,303
  302 GV=GVL
      GOTO 304
  303 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
  304 CONTINUE
      IF(TM-1.)2,2,6
    2 GV=0.
    6 CONTINUE
```

```
      FG=FM*GV
      VD2=(CXU*DV+CXA*DA-CL1*DTH+FG*CXI*(C52*DTH+C51*THD+C50*TDD1))*F10
      ALD2=(CZU*DV+CZA*DA+(CZTD+PM+C51*FG*CZDE)*TD2+C52*FG*CZDE*T2+CZDE*
     1(DE+C50*TDD1*FG))/F11
      TDD2=(CMU*DV+CMA*DA+CMAD*ALD2+(CMTD+C51*FG*CMDE)*TD2*CMDE*(DE+C52*
     1FG*T2)+TV)/(YI-C50*FG*CMDE)
      DD2=FM*GV*(C50*TDD1+C51*THD+C52*DTH)
      DD15=ABS(DD2)
      IF(DD15-.26)43,42,42
   42 DD2=.26*DD2/DD15
      VD2=(CXU*DV+CXA*DA-CL1*DTH+CXI*(DD2+DE))*F10
      ALD2=(CZU*DV+CZA*DA+CZTD*TD2+CZDE*(DD2+DE))/F11
      TDD2=(CMU*DV+CMA*DA+CMAD*ALD2+CMTD*TD2+CMDE*(DD2+DE))/YI
   43 CONTINUE
      V=V1+VD2*DL
      AL=AL1+ALD2*DL
      THD=TD1+TDD2*DL
      TH=T1+TD1*DL+.5*TDD2*DL*DL
      THP=57.3*TH
      IF(VO)11,12,11
   11 ALP=57.3*AL
      GP=THP-ALP
      GOTO13
   12 ALP=0.
      GP=THP-ALP
      ALP=AL
   13 CONTINUE
      GL=ABS(GP)
      IF(GL-90.)79,81,81
   79 CONTINUE
      IF(N-1)20,20,21
   20 N=N+1
      GOTO 80
   21 N=0
      DD2=FM*GV*(C50*TDD2+C51*THD+C52*TH)
      DX=57.3*DD2
      DX1=57.3*DD1
      IF(V)606,607,606
  606 WRITE(6,104)TM,V,DX1,DX,ALP,THP,GP
      GOTO608
  607 WRITE(6,605)TM,V,DX1,DX,ALP,THP,GP
  608 CONTINUE
  104 FORMAT(3X,3HTM=,F6.2,1X,2HV=,F5.1,1X,4HDX1=,F9.5,1X,4H DX=,F9.5,1X
     1,4HALP=,F10.6,1X,4HTHP=,F10.6,1X,3HGP=,F10.6)
  605 FORMAT(3X,3HTM=,F6.2,1X,2HV=,F5.1,1X,4HDX1=,F9.5,1X,4H DX=,F9.5,1X
     1,4H  W=,F10.6,1X,4HTHP=,F10.6,1X,3HTH=,F10.6)
   80 TM=TM+DTM
   81 IF(SG)97,30,98
   30 CONTINUE
      END
*     LIST(STOP)
      LIST
*     DATA
.000194        0.             .0062          0.             .00551
-.0000042      .0000079       -.000009       -.000043       0.
0.             .000000078     .000000008     0.             -.0000043
-.041          .00000336      0.             -.0013         0.
.0045
10.     1.     0.     0.
4.      1.     2.     4.     1.
```


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APPENDIX D

PROGRAM FOR SOLUTION OF LATERAL EQUATIONS

v	ϕ	ψ
$C_{Y_v} - \frac{m'}{V} s$	C_L	$(-m + C_{Y_\psi})s$
C_{ℓ_v}	$sC_{\ell_\phi} - I'_X s^2$	$C_{\ell_\psi} s$
C_{η_v}	$C_{\eta_\phi} s$	$C_{\eta_\psi} s - I'_Z s^2$

		$A's^4$	$B's^3$	$C's^2$	$D's$	E'	
BASE VALUES		$-\frac{m'}{V} I'_X I'_Z$	$C_{Y_v} I'_X I'_Z$ $\frac{m'}{V}(I'_Z C_{\ell_\phi} + I_X C_{\eta_\psi})$	$-C_{Y_v}(I'_Z C_{\ell_\phi} + I_X C_{\eta_\psi})$ $-\frac{m'}{V}(C_{\ell_\phi} C_{n_\psi} - C_{\ell_\psi} C_{\eta_\phi})$ $C_{\ell_v} I'_Z C_{Y_\phi}$ $C_{\eta_v} I'_X C_{Y_\psi}$ $-m C_{\eta_v} I'_X$	$C_{Y_v}(C_{\ell_\phi} C_{\eta_\psi} - C_{\ell_\psi} C_{\eta_\phi})$ $C_{\ell_v}(C_L I'_Z - C_{Y_\phi} C_{\eta_\psi} + C_{Y_\psi} C_{\eta_\phi})$ $C_{\eta_v}(C_{Y_\phi} C_{\ell_\psi} - C_{Y_\psi} C_{\ell_\phi})$	$C_{\eta_v} C_L \quad C_L C_{\ell_\psi}$ $-C_{\ell_v} C_L \quad C_{\eta_\psi}$	
ϕ SAS CONTRIBUTIONS	GAIN C_{60}			$\frac{m'}{V} I'_Z C_{\ell_{A1}}$ (1)	$-C_{Y_v} I_Z C_{\ell_{AI}}$ $-\frac{m}{V} C_{\eta_\phi} C_{\ell_{AI}}$ $\frac{m'}{V} C_{\ell_\psi} C_{\eta_{AI}}$ $C_{\ell_v} I'_Z C_{Y_{AI}}$ (2)	$m' C_{\eta_v} C_{\ell_{AI}}$ $C_{Y_v} C_{\eta_\psi} C_{\ell_{AI}}$ $C_{Y_v} C_{\ell_\psi} C_{\eta_{AI}}$ $C_{\ell_v} C_{Y_\psi} C_{\eta_{AI}}$ $-m' C_{\ell_v} C_{\eta_{AI}}$ $C_{\ell_v} C_{\eta_\psi} C_{Y_{AI}}$ $C_{\eta_v} C_{\ell_\psi} C_{Y_{AI}}$ $C_{\eta_v} C_{Y_\psi} C_{\ell_{AI}}$ (3)	$\frac{dA_I}{d\psi}$
	C_{61}		(1)	(2)	(3)		$\frac{dA_I}{d\phi}$
	C_{62}	(1)	(2)	(3)			$\frac{dA_I}{d\phi}$
ψ SAS CONTRIBUTIONS	C_7			(5)	(6)	(7)	(8)
	C_8		(5)	(6)	(7)	(8)	$\frac{d\theta_{TR}}{d\psi}$
	C_9	(5) $\frac{m'}{V} I_X C_{\eta_{\theta_{TR}}}$	(6) $-C_{Y_v} I_X C_{\eta_{\theta_{TR}}}$ $-\frac{m}{V} C_{\ell_\phi} C_{\eta_{\theta_{TR}}}$ $-\frac{m}{V} C_{\eta_\phi} C_{\ell_\phi}$ $C_{\eta_v} I_X C_{Y_{\theta_{TR}}}$	(7) $C_{Y_v} C_{\ell_\phi} C_{\eta_{\theta_{TR}}}$ $-C_{Y_v} C_{\eta_\psi} C_{\ell_{\theta_{TR}}}$ $C_{\ell_v} C_{\eta_\phi} C_{Y_{\theta_{TR}}}$ $-C_{\ell_v} C_{Y_\phi} C_{\eta_{\theta_{TR}}}$ $C_{\eta_v} C_{Y_\phi} C_{\ell_{\theta_{TR}}}$ $-C_{\eta_v} C_{\ell_\phi} C_{Y_{\theta_{TR}}}$	(8) $C_{\eta_v} C_L C_{\ell_{\theta_{TR}}}$ $C_{\ell_v} C_L C_{\eta_{\theta_{TR}}}$		$\frac{d\theta_{TR}}{d\psi}$

*NOTE TRIANGULAR RELATIONSHIP

$$(1)\ \frac{\phi}{\psi}\ \frac{\phi}{\psi}\ \frac{\dot\phi}{\psi}$$

(1) QUINTIC

TABLE D.1 Expansion of Lateral-Directional Derivatives

```
*                    52, 392
*     LIST(START)
C                       SOLUTION OF LATERAL EQUATIONS
C
C              SV                        SY                          T
C        -PM(S)+CYV          (-PM*V+CYSD)(S)                 CYTD(S)+CL
C                 CLV                  CLSD(S)          -XI(S**2)+CLTD(S)
C                 CNV        -ZI(S**2)+CNSD(S)                  CNTD(S)
C
C   CARD  COLUMN  SYMBOL
C     1   01-15    PM
C     1   11-20    V        VELOCITY             FT/SEC
C     1   21-30    CL1      LIFT COEFFICIENT     W/Q*AD   AD DISC AREA
C     1   31-40    XI       MOMENT OF INERTIA    IXX/Q*AD*ROTR
C     1   41-50    ZI       MOMENT OF INERTIA    IZZ/Q*AD*ROTR
C     2    1-10    CYV
C     2   11-20    CLV
C     2   21-30    CNV
C     2   31-40    CYSD
C     2   41-50    CLSD
C     2   51-60    CNSD
C     2   61-70    CYPHD
C     3    1-10    CLPHD
C     3   11-20    CNPHD
C     3   21-30    CYDS
C     3   31-40    CLDS
C     3   41-50    CNDS
C     4    1-10    CYDR
C     4   11-20    CLDR
C     4   21-30    CNDR
C     5    1-10    FM            MODEL GAIN
C     5   11-20    GV           GAIN
C     5   21-30    C60          AUTOPILOT COEFFICIENT S2
C     5   31-40    C61
C     5   41-50    C62
C
C                            TYPICAL INPUTS
C1.26         100.        .405        .0071       .0278
C-.00094      -.000072    .0004       -.011       0.          -.193
C0.           -.000085    .000015     -.405       -.116       - .0201
C.114         .025        -.114
C0.           0.          0.          0.          0.
C1
C4.           1.          1.          2.          4.
C-1
C.000194      1.          .0062       .00011      .00043
C-.000061     -.0000076.0000052       .000148     0.          -.000148
C0.           .0000018    .00000031   -.0045      -.0013      -.00023
C.0018        .0004       -.0018
C0.           0.          0.          0.          0.
C1
C4.           1.          1.          2.          4.
C0
C      PROB
       DIMENSION XCOF(11),COF(11),ROOTR(10),ROOTI(10),Z(4)
       COMMON XCOF,COF,M,ROOTR,ROOTI,IER
    11 FORMAT(2X,6E17.8)
    12 FORMAT(1X,50H   REAL       IMAG       PERIOD      T 1/2      WN
      110H    DR     /1X,6F10.4)
```

```
   97 CONTINUE
      J=0
      READ(5,1)PM,V,CL,XI,ZI
      READ(5,1)CYV,CLV,CNV,CYSD,CLSD,CNSD
      READ(5,1)CYPHD,CLPHD,CNPHD,CYDS,CLDS,CNDS
      READ(5,1)CYDR,CLDR,CNDR
      WRITE(6,95)PM,V,CL,XI,ZI
      WRITE(6,94)CYV,CLV,CNV,CYSD,CLSD,CNSD
      WRITE(6,93)CYPHD,CLPHD,CNPHD,CYDS,CLDS,CNDS
      WRITE(6,92)CYDR,CLDR,CNDR
   92 FORMAT(1X,5HCYDR=,E15.8,1X,5HCLDR=,E15.8,1X,5HCNDR=,E15.8)
   93 FORMAT(1X,6HCYPHD=,E15.8,1X,6HCLPHD=,E15.8,1X,6HCNPHD=,E15.8,1X,5H
     1CYDS=,E15.8,1X,5HCLDS=,E15.8,1X,5HCNDS=,E15.8)
   94 FORMAT(1X,4HCYV=,E15.8,1X,4HCLV=,E15.8,1X,4HCNV=,E15.8,1X,5HCYSD=,
     1E15.8,1X,5HCLSD,E15.8,1X,5HCNSD=,E15.8)
   95 FORMAT(1X,3HPM=,E15.8,1X,2HV=,E15.8,1X,3HCL=,E15.8,1X,3HXI=,E15.8,
     11X,3HZI=,E15.8)
C     IF INPUTS CYB  IF NOT REMOVE NEXT 3 CARDS IE CYV=CYV/V
C     CYV=CYV/V
C     CLV=CLV/V
C     CNV=CNV/V
   98 READ(5,1)FM,GV,C60,C61,C62
      WRITE(6,91)FM,GV,C60,C61,C62
   91 FORMAT(1X,3HFM=,F6.3,1X,3HGV=,F6.3,1X,4HC60=,F6.3,1X,4HC61=,F6.3,1
     1X,4HC62=,F6.3)
      FG=FM*GV
      M=4
      C10S=FG*C60
      C10=FG*C61
      C11=FG*C62
C     FOR HOVER SET V=1 AND PM=M/(Q*AD)  Q=RHO*VTIP*VTIP
      IF(V-1.)3,3,4
    3 F10=0.
      F11=0.
      F12=0.
      WRITE(6,6)
    6 FORMAT(5HHOVER)
      GOTO5
    4 F10=CNV*XI*CYSD
      F11=CNV*CLPHD*PM-CLV*PM*CNPHD
      F12=PM*CNV*CLDS-PM*CLV*CNDS
    5 CONTINUE
      A=-PM*XI*ZI/V
      B=CYV*XI*ZI+PM*(CLPHD*ZI+CNSD*XI)/V
      C=-CYV*(CLPHD*ZI+XI*CNSD)-PM*(CLPHD*CNSD-CNPHD*CLSD)/V+CLV*CYPHD*Z
     1I+F10
      C=C-CNV*XI*PM
      D=CYV*(CLPHD*CNSD-CNPHD*CLSD)+CLV*(ZI*CL-CYPHD*CNSD+CNPHD*CYSD)+CN
     1V*(CYPHD*CLSD-CLPHD*CYSD)
      D=D+F11
      E=-CLV*CL*CNSD+CNV*CL*CLSD
      X1=CYV*(CLDS*CNSD-CNDS*CLSD)+CLV*(-CYDS*CNSD+CYSD*CNDS)+CNV*(CYDS*
     1CLSD-CYSD*CLDS)
      X1=X1+F12
      X2=-CYV*CLDS*ZI-PM*(CLDS*CNSD-CLSD*CNDS)/V+CLV*CYDS*ZI
      X3=PM*CLDS*ZI/V
      Y1=PM*XI*CNDR/V
      Y2=-CYV*XI*CNDR-(PM/V)*(CLPHD*CNDR-CLDR*CNPHD)+CNV*CYDR*XI
      Y3=CYV*(CLPHD*CNDR-CLDR*CNPHD)+CLV*(CYDR*CNPHD-CYPHD*CNDR)+CNV*(CY
     1PHD*CLDR-CYDR*CLPHD)
```

```
      Y4=CNV*CL*CLDR-CLV*CL*CNDR
      E1=C11*X1
      D1=C11*X2+C10*X1
      C1=C11*X3+C10*X2+C10S*X1
      B1=C10*X3+C10S*X2
      A1=C10S*X3
      A=A+A1
      B=B+B1
      C=C+C1
      D=D+D1
      E=E+E1
      A1=1.
      B1=B/A
      C1=C/A
      D1=D/A
      E1=E/A
      XCOF(1)=E1
      XCOF(2)=D1
      XCOF(3)=C1
      XCOF(4)=B1
      XCOF(5)=A1
      WRITE(6,1)A1,B1,C1,D1,E1
      CALLROLRT(XCOF,COF,M,ROOTR,ROOTI,IER)
      DO20I=1,4
      IF(ROOTI(I))81,80,81
   80 P=200000.
      GOTO82
   81 P=2.*3.1417/ROOTI(I)
   82 D=.69/ROOTR(I)
      WN=(ROOTI(I)**2+ROOTR(I)**2)**.5
      DR=-ROOTR(I)/WN
   20 WRITE(6,90)ROOTR(I),ROOTI(I),P,D,WN,DR
   90 FORMAT(1X,6HROOTR=,E12.5,1X,6HROOTI=,E12.5,1X,7HPERIOD=,E12.5,1X,1
     14H TIME TO HALF=,E12.5,1X,3HWN=,E12.5,1X,3HDR=,E12.5)
    1 FORMAT(7F10.6)
    2 FORMAT(I10)
      READ(5,2)MORE
      IF(MORE)97,30,98
   30 CONTINUE
      END
      SUBROUTINE ROLRT(XCOF,COF,M,ROOTR,ROOTI,IER)
      DIMENSION XCOF(10),COF(10),ROOTR(10),ROOTI(10)
      IFIT=0
      N=M
      IER=0
      IF(XCOF(N+1))10,25,10
   10 IF(N)15,15,32
   15 IER=1
   20 RETURN
   25 IER=4
      GOTO20
   30 IER=0
      GOTO20
   32 IF(N-36)35,35,30
   35 NX=N
      NXX=N+1
      N2=1
      KJ1=N+1
      DO40L=1,KJ1
      MT=KJ1-L+1
```

```
40 COF(MT)=XCOF(L)
45 XO=.00500101
   YO=.01000101
   IN=0
50 X=XO
   XO=-10.*YO
   YO=-10.*X
   X=XO
   Y=YO
   IN=IN+1
   GOT 159
55 IFIT=1
   XPR=X
   YPR=Y
59 ICT=0
60 UX=0.
   UY=0.
   V=0.
   YT=0.
   XT=1.
   U=COF(N+1)
   IF(U)65,130,65
65 DO70I=1,N
   L=N-I+1
   XT2=X*XT-Y*YT
   YT2=X*YT+Y*XT
   U=U+COF(L)*XT2
   V=V+COF(L)*YT2
   FI=I
   UY=UY-FI*YT*COF(L)
   UX=UX+FI*XT*COF(L)
   XT=XT2
70 YT=YT2
   SUMSQ=UX*UX+UY*UY
   IF(SUMSQ)75,110,75
75 DX=(V*UY-U*UX)/SUMSQ
   X=X+DX
   DY=-(U*UY+V*UX)/SUMSQ
   Y=Y+DY
78 IF(ABS(DY)+ABS(DX)-.000001)100,80,80
80 ICT=ICT+1
   IF(ICT-500)60,85,85
85 IF(IFIT)100,90,100
90 IF(IN-5)50,95,95
95 IER=3
   GOTO20
100 DO105L=1,NXX
   MT=KJ1-L+1
   TEMP=XCOF(MT)
   XCOF(MT)=COF(L)
105 COF(L)=TEMP
   ITEMP=N
   N=NX
   NX=ITEMP
   IF(IFIT)120,55,120
110 IF(IFIT)115,50,115
115 X=XPR
   Y=YPR
120 IFIT=0
122 IF(ABS(Y/X)-0.00001)135,125,125
```

```
  125 ALPHA=X+X
      SUMSQ=X*X+Y*Y
      N=N-2
      GOTO140
  130 X=0
      NX=NX
      NXX=NXX-1
  135 Y=0
      SUMSQ=0.
      ALPHA=X
      N=N-1
  140 COF(2)=COF(2)+ALPHA*COF(1)
      IF(N-2)147,146,146
  147 NN=2
      GOTO145
  146 NN=N
  145 DO150L=2,NN
      M11=L+1
  150 COF(M11)=COF(M11)+ALPHA*COF(L)-SUMSQ*COF(L-1)
  155 ROOTI(N2)=Y
      ROOTR(N2)=X
      N2=N2+1
      IF(SUMSQ)160,165,160
  160 Y=-Y
      SUMSQ=0.
      GOTO155
  165 IF(N)20,20,45
      RETURN
      END
*     LIST(STOP)
      LIST
*     DATA
1,26       100.        .405        .0071       .0278
-.00094    -.000072    .0004       -.011       0.          -.193
0.         -.000085    .000015     -.405       -.116       - .0201
.114       .025        -.114
0.         0.          0.          0.          0.
1
4.         1.          1.          2.          4.
-1
.000194    1.          .0062       .00011      .00043
-.000061   -.00000076.00000052     .000148     0.          -.000148
0.         .0000018    .00000031   -.0045      -.0013      -.00023
.0018      .0004       -.0018
0.         0.          0.          0.          0.
1
4.         1.          1.          2.          4.
0
      PROB
```


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APPENDIX E

LATERAL TRANSIENT MOTION PROGRAM

```
*
$      MAXO(2400)
*      LIST(START)
C                           LATERAL-DIRECTIONAL MOTION
C                              FEEDBACK GAINS C60 C61 C62
C
C  CARD  COLUMN  SYMBOL
C    1    01-15   PM
C    1    11-20   V          VELOCITY              FT/SEC
C    1    21-30   CL1        LIFT COEFFICIENT      W/Q*AD    AD DISC AREA
C    1    31-40   YI         MOMENT OF INERTIA     IXX/Q*AD*ROTR
C    1    41-50   XI         MOMENT OF INERTIA     IZZ/Q*AD*ROTR
C    2     1-10   CYV
C    2    11-20   CLV
C    2    21-30   CNV
C    2    31-40   CYSD
C    2    41-50   CLSD
C    2    51-60   CNSD
C    2    61-70   CYPHD
C    3     1-10   CLPHD
C    3    11-20   CNPHD
C    3    21-30   CYDS
C    3    31-40   CLDS
C    3    41-50   CNDS
C    4     1-10   CYDR
C    4    11-20   CLDR
C    4    21-30   CNDR
C    5    01-15   RTU
C    5    16-30   RTL
C    5    31-45   GVU
C    5    46-60   GVL
C         01-15   C60
C    6    16-31   C61
C    6    31-45   C62
C    6    46-60   SG         0 END,-1 NEW PM, 1 NEW GAIN
C
C                           TYPICAL INPUTS
C
C1.26        100.         .405        .0071       .0278
C-.00094     -.000072     .0004       -.011       0.          -.193
C0.          -.000085     .000015     -.405       -.116       - .0201
C.114        .025         -.114
C10.         .1           4.          .5
C.25         1.           2.          4.          1.
C10.         .1           4.          .5
C1.0         1.           2.          4.          -1.
C.000194     0.           .0062       .00011      .00043
C-.000061    -.00000076.0000052       .000148     0.          -.000148
C0.          .0000018     .00000031   -.0045      -.0013      -.00023
C.0018       .0004        -.0018
C10.         .1           4.          .5
C.25         1.           2.          4.          1.
C10.         .1           4.          .5
C1.          1.           2.          4.          0.
C       PROB
   100 CONTINUE
       READ(5,1)PM,V,CL,XI,ZI
       READ(5,1)CYV1,CLV1,CNV1,CYSD,CLSD,CNSD
       READ(5,1)CYTD,CLTD,CNTD,CYDS,CLDS,CNDS
```

```
      READ(5,1)CYDR,CLDR,CNDR
    1 FORMAT(7F10.6)
      WRITE(6,2)PM,V,CL,XI,ZI
      WRITE(6,3)CYV1,CLV1,CNV1,CYSD,CLSD,CNSD
      WRITE(6,4)CYTD,CLTD,CNTD,CYDS,CLDS,CNDS
      WRITE(6,5)CYDR,CLDR,CNDR
    2 FORMAT(1X,3HPM=,F6.3,1X,2HV=,F5.1,1X,3HCL=,F6.3,1X,3HXI=,F7.4,1X,3
     1HZI=,F7.4)
    3 FORMAT(1X,5HCYV1=,F10.6,1X,5HCLV1=,F10.6,1X,5HCNV1=,F10.6,1X,5HCYS
     1D=,F10.6,1X,5HCLSD=,F10.6,1X,5HCNSD=,F10.6)
    4 FORMAT(1X,5HCYTD=,F10.6,1X,5HCLTD=,F10.6,1X,5HCNTD=,F10.6,1X,5HCYD
     1S=,F10.6,1X,5HCLDS=,F10.6,1X,5HCNDS=,F10.6)
    5 FORMAT(1X,5HCYDR=,F10.6,1X,5HCLDR=,F10.6,1X,5HCNDR=,F10.6)
   96 READ(5,1)RTU,RTL,GVU,GVL
      READ(5,1)FM,C60,C61,C62,SG
      WRITE(6,9)RTU,RTL,GVU,GVL
      WRITE(6,6)FM,C60,C61,C62
    9 FORMAT(1X,4HRTU=,F6.3,1X,4HRTL=,F6.3,1X,4HGVU=,F6.3,1X,4HGVL=,F6.3
     1)
    6 FORMAT(1X,4H FM=,F6.3,1X,4HC60=,F6.3,1X,4HC61=,F6.3,1X,4HC62=,F6.3
     1)
      WRITE(6,87)
   87 FORMAT(3X,2HTM,10X,2HSV,10X,2HSY,10X,2HTH,10X,2HDR,9X,3HDXR,9X,3HD
     1XA,9X,4HALAT)
C     IF INPUT CYV REMOVE NEXT 3 CARDS OKE FOR CYB
C     CNV=CNV1/V
C     CLV=CLV1/V
C     CYV=CYV1/V
      CYV=CYV1
      CNV=CNV1
      CLV=CLV1
      SVD2=0.
      DD1=0.
      DD2=0.
      DI2=0.
      DRMX=1./57.3
      TDD2=0.
      SV=0.
      SY=0.
      TH=0.
      TDD=0.
      SVD=0.
      SD=0.
      TD=0.
      NN=0
      TM=0.
      DTM=.05
      CD=0.
      DL=DTM/2.
      DR=0.
C     FOR HOVER WHEN V=0  PM=M/(Q*AP)  Q=RHO*VTIP*VTIP
      IF(V)10,10,11
   10 F10=C.
      F11=1./PM
      GOTO12
   11 F10=PM
      F11=V/PM
   12 CONTINUE
      DO80 JJ=1,800
      CD1=CD
```

```
      T=TM
      IF(T-.5)70,71,72
   70 CD=T/.5
      GOTO75
   71 CD=1.
      GOTO75
   72 IF(T-1.)73,74,74
   73 CD=(1.-T)/.5
      GOTO75
   74 CD=0.
   75 DR=CD1*DRMX
      RT=ABS((DD2-DD1)/DTM)
      IF(RT-RTU)201,201,200
  200 GV=GVU
      GOTO204
  201 IF(RT-RTL)202,202,203
  202 GV=GVL
      GOTO204
  203 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
  204 CONTINUE
      IF(TM-1.)350,350,351
  350 GV=0.
  351 CONTINUE
      FG=FM*GV
      SDD=(CNV*SV+CNSD*SD+(CNTD+FG*C61*CNDS)*TD+CNDS*FG*C62*TH+CNDS*FG*C
     160*TDD+CNDR*DR)/ZI
      SVD1=(CL*SIN(TH)+CYV*SV+CYSD*SD+(CYTD+FG*C61*CYDS)*TD+C60*FG*CYDS*
     1TDD+C62*FG*CYDS*TH+CYDR*DR-F10*SD)*F11
      TDD=(CLV*SV+CLSD*SD+(CLTD+FG*C61*CLDS)*TD+FG*C62*CLDS*TH+CLDR*DR)/
     1(XI-FG*C60*CLDS)
      DD1=FM*GV*(C60*TDD+C61*TD+C62*TH)
      DD15=ABS(DD1)
      IF(DD15-.26)41,40,40
   40 DD1=.26*DD1/DD15
      SDD=(CNV*SV+CNSD*SD+CNTD*TD+CNDS*DD1+CNDR*DR)/ZI
      SVD1=(CL*SIN(TH)+CYV*SV+CYSD*SD+CYTD*TD+CYDS*DD1+CYDR*DR-F10*SD2)*
     1F11
      TDD=(CLV*SV+CLSD*SD+CLTD*TD+CLDS*DD1+CLDR*DR)/XI
   41 CONTINUE
      SD1=SD+SDD*DL
      TD1=TD+TDD*DL
      SV1=SV+SVD1*DL+DI2
      S1=SY+SD1*DL
      T1=TH+TD1*DL
      TD2=TD1+TDD*DL
      SV2=SV+SVD1*DL+DI2
      T2=T1+TD1*DL
      SD2=SD1+SDD*DL
      RT=ABS((DD1-DD2)/DTM)
      IF(RT-RTU)301,300,300
  300 GV=GVU
      GOTO304
  301 IF(RT-RTL)302,302,303
  302 GV=GVL
      GOTO304
  303 GV=GVL+((RT-RTL)/(RTU-RTL))*(GVU-GVL)
  304 CONTINUE
      IF(TM-1.)352,352,353
  352 GV=0.
  353 CONTINUE
```

```
      DR=CD*DRMX
      FG=FM*GV
      SDD2=(CNV*SV2+CNSD*SD2+(CNTD+FG*C61*CNDS)*TD2+CNDS*FG*C62*T2+CNDS*
     1FG*C60*TDD+CNDR*DR)/ZI
      SVD2=(CL*SIN(T2)+CYV*SV2+CYSD*SD2+(CYTD+FG*C61*CYDS)*TD2+C60*FG*CY
     1DS*TDD+C62*FG*CYDS*TH +CYDR*DR-F10*SD2)*F11
      TDD2=(CLV*SV2+CLSD*SD2+(CLTD+FG*C61*CLDS)*TD2+FG*C62*CLDS*T2+CLDR
     1*DR)/(XI-FG*C60*CLDS)
      DD2=FM*GV*(C60*TDD2+C61*TD2+C62*T2)
      DD15=ABS(DD2)
      IF(DD15-.26)43,42,42
   42 DD2=.26*DD2/DD15
      SDD2=(CNV*SV2+CNSD*SD2+CNTD*TD2+CNDS*DD2+CNDR*DR)/ZI
      TDD2=(CLV*SV2+CLSD*SD2+CLTD*TD2+CLDS*DD2+CLDR*DR)/XI
      SVD2=(CL*SIN(T2)+CYV*SV2+CYSD*SD2+CYTD*TD2+CYDS*DD2+CYDR*DR-F10*SD
     12)*F11
   43 CONTINUE
      SV=SV1+SVD2*DL+DI2
      SD=SD1+SDD2*DL
      ALAT=(SVD2+V*SD)/32.2
      TD=TD1+TDD2*DL
      SY=S1+SD *DL
      TH=T1+TD *DL
      TDD=TDD2
      SYP=SY*57.3
      THP=TH*57.3
      DRP=DR*57.3
      DXR=57.3*DD1
      DXA=57.3*DD2
      IF(NN-1)20,20,21
   20 NN=NN+1
      GOTO80
   21 NN=0
      WRITE(6,13)TM,SV,SYP,THP,DRP,DXR,DXA,ALAT
   80 TM=TM+DTM
   13 FORMAT(8E12.5)
      IF(SG)100,30,98
   30 CONTINUE
      END
*     LIST(STOP)
      LIST
*     DATA
1.26        100.        .405        .0071       .0278
-.00094     -.000072    .0004       -.011       0.          -.193
0.          -.000085    .000015     -.405       -.116       - .0201
.114        .025        -.114
10.         .1          4.          .5
.25         1.          2.          4.          1.
10.         .1          4.          .5
1.0         1.          2.          4.          -1.
.000194     0.          .0062       .00011      .00043
-.000061    -.00000076.0000052      .000148     0.          -.000148
0.          .0000018    .00000031   -.0045      -.0013      -.00023
.0018       .0004       -.0018
10.         .1          4.          .5
.25         1.          2.          4.          1.
10.         .1          4.          .5
1.          1.          2.          4.          0.
      PROB
```


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APPENDIX F

CALCULATIONS

TABLE F.1

TYPICAL LATERAL STABILITY DERIVATIVES

AND NOTATION USED IN EQUATIONS OF MOTION

SYMBOL NORMAL	SYMBOL FORTRAN		TYPICAL VALUES AIRCRAFT SYSTEM	TYPICAL VALUES HELICOPTER SYSTEM	
	PM	Mass Coefficient M*V/Q*AD	1.26	.00194	.0425
	V	Velocity	100	0	169
	CL	Lift Coefficient W/(Q*AD)	.405	.0062	.0081
	XI	Moment Coefficient IXX/(Q*AD*ROTR)	.0071	.00011	
	ZI	Moment Coefficient IZZ/(Q*AD*ROTR)	.0278	.00043	
C_{Y_ν}	CYV	Side Force Due to Sideslip Velocity	-.00094	-6.1×10^{-5}	-3.75×10^{05}
C_{ℓ_ν}	CLV	Rolling Moment Due to Sideslip Velocity	-.000072	-7.6×10^{-7}	-9.9×10^{-7}
C_{n_ν}	CNV	Yawing Moment due to Sideslip Velocity	.0004	5.2×10^{-6}	4.1×10^{-5}
C_{Y_ψ}	CYSD	Side Force due to Yawing Velocity	-.011	1.48×10^{-4}	-6.1×10^{-3}
C_{ℓ_ψ}	CLSD	Rolling Moment Due to Yawing Velocity	0	0	0
C_{n_ψ}	CNSD	Yawing Moment due to Yawing Velocity	-.193	-1.48×10^{-4}	-9.1×10^{-3}
C_{Y_ϕ}	CYPHD	Side Force Damping	0	0	0
C_{ℓ_ϕ}	CLPHD	Roll Damping	-.000085	1.8×10^{-6}	1.65×10^{-5}
C_{n_ϕ}	CNPHD	Yaw Damping	.000015	3.1×10^{-7}	-1.43×10^{-6}

TABLE F. 1

TYPICAL LATERAL STABILITY DERIVATIVES
AND NOTATION USED IN EQUATIONS OF MOTION
(Continued)

SYMBOL NORMAL	SYMBOL FORTRAN		TYPICAL VALUES AIRCRAFT SYSTEM	TYPICAL VALUES HELICOPTER SYSTEM	
$-C_{Y_{A1}}$	CYDS	Side Force due to Lateral Cyclic Control	-.405	-4.5×10^{-3}	8.1×10^{-3}
$-C_{\ell_{A1}}$	CLDS	Rolling Moment due to Lateral Cyclic	-.116	-1.3×10^{-3}	1.8×10^{-3}
$-C_{n_{A1}}$	CNDS	Yawing Moment due to Lateral Cyclic	-.0201	-2.3×10^{-4}	1.6×10^{-3}
$C_{Y_{TR}}$	CYDR	Side Force due to Tail Rotor Pitch	.114	.0018	
$C_{\ell_{TR}}$	CLDR	Rolling Moment due to Tail Rotor Pitch	.025	.0004	
$C_{n_{TR}}$	CNDR	Yawing Moment due to Tail Rotor Pitch	-.114	-.0018	-3.5×10^{-3}

θ_c = TIC, Main Rotor Collective Pitch

B_1 = Main Rotor Longitudinal Cyclic Pitch

A_1 = Main Rotor Lateral Cyclic Pitch

θ_{tR} = Tail Rotor Collective Pitch

AD = Disc Area = $\Pi * \overline{ROTR}^2$

ROTR = Rotor Radius

IXX, IYY, IZZ Airplane Moments of Inertia

M = Aircraft Mass

W = Aircraft Weight

Q = RHØ * VTIP * VTIP Helicopter System

Q = RHØ * V * V/2 Aircraft System

TABLE F.1 (cont'd)

TYPICAL LONGITUDINAL STABILITY DERIVATIVES

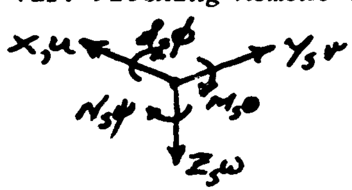
AND NOTATION USED IN EQUATIONS OF MOTION

SYMBOL NORMAL	SYMBOL FORTRAN		TYPICAL VALUES AIRCRAFT SYSTEM I	TYPICAL VALUES HELICOPTER SYSTEM II	TYPICAL VALUES HELICOPTER SYSTEM III
	PM	Mass Coefficient	1.26	.000194	.0425
	V	Velocity	100	0	169
C_L	CL1	Lift Coefficient	.405	.0062	.0081
α	ALPHA	Angle of Attack	0	0	0
	YI	Inertia Coefficient	.033	.00051	
C_{X_μ}	CXU	Var. of Drag and Thrust with Velocity	.0000486	-4.2×10^{-6}	-1.0×10^{-5}
C_{X_α}	CXA	Var. of Drag and Thrust with Angle Attack	.05207	7.9×10^{-6}	-3.0×10^{-3}
C_{Z_μ}	CZU	Var. of Lift with Velocity	-.000173	-9×10^{-6}	3.7×10^{-6}
C_{Z_α}	CZA	Var. of Lift with Angle Attack	-.793	-4.3×10^{-5}	-3.15×10^{-2}
$C_{Z_{\dot{\alpha}}}$	CZAD	Var. of Lift with Angle Attack Rate	0	0	0
$C_{Z_{\dot{\theta}}}$	CZTD	Var. of Lift with Pitch Velocity	0	0	0

TABLE F.1 (continued)

TYPICAL LONGITUDINAL STABILITY DERIVATIVES
AND NOTATION USED IN EQUATIONS OF MOTION
(Continued)

SYMBOL NORMAL	SYMBOL FORTRAN		TYPICAL VALUES AIRCRAFT SYSTEM	TYPICAL VALUES HELICOPTER SYSTEM	
C_{m_μ}	CMU	Velocity Stability	.00035	$7.8x.0^{-8}$	$2.5x10^{-6}$
C_{m_α}	CMA	Angle Attack Stability	0	$8x10^{-9}$	$-1.1x10^{-3}$
$C_{m_{\dot\alpha}}$	CMAD	Angle Attack Damping	-.00088	0	$-7.4x10^{-5}$
$C_{m_{\dot\theta}}$	CMTD	Pitch Damping	-.0654	$-4.3x10^{-6}$	$-6.1x10^{-3}$
$C_{x_{\theta c}}$	CXTC	Var. Drag Due to Collective Pitch			$-8.1x10^{-3}$
$C_{z_{\dot\theta c}}$	CZTC	Var. Lift due to Collective Pitch	-3.14	-.041	$-7.9x10^{-2}$
$C_{m_{\theta c}}$	CMTC	Var. Pitching Moment due to Coll. Pitch	.155	$3.36x10^{-6}$	$5.4x10^{-4}$
$C_{x_{BIC}}$	CXBI	Var. Drag Due to Cyclic Pitch Control	.353	.0045	$1.06x10^{-2}$
$C_{z_{BIC}}$	CZBI	Var. Lift due to Cyclic Pitch	.793	0	$3.14x10^{-2}$
$C_{m_{BIC}}$	CMBI	Var. Pitching Moment due to-Cyclic Pitch	-.168	-.0013	$-1.33x10^{-3}$
C_{mi}	CMI	Var. Pitching Moment due to Tail Incidence	-.0144	0	$-1.9x10^{-3}$



Forces	X	Z	Y
Moments	M	N	L
Angular Velocities	$\dot\theta$	$\dot\psi$	$\dot\phi$
Velocities	μ	ν	ω

TABLE F.2

EFFECTS OF CHANGES OF LONGITUDINAL DERIVATIVES
V=100

Q=RHO*V*V/2.   A=3.14*R*R   CX=X/(Q*A)   CM=M/(Q*A*R)   PM=1.26   CL=.405   YI=.033

V=	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
CXU=	.00486	.00486	.00486	.00486	-.00486	.00397	.00465	.00486	.00486	.00486	.00486	.00486	.00486	.00486	.00486	.00486	.00486	.00486
CXA=	.05207	.05207	.05207	.05207	.05207	.05207	-.05207	.10400	.05207	.05207	.05207	.05207	.05207	.05207	.05207	.05207	.05207	.05207
CZU=	-.00017	-.00017	-.00017	-.00017	-.00017	-.00017	-.00017	-.00017	-.00036	-.00017	-.00017	-.00017	-.00017	-.00017	-.00017	-.00017	-.00017	-.00017
CZA=	-.79300	-.79300	-.79300	-.79300	-.79300	-.79300	-.79300	-.79300	-.79303	1.40000	-.79300	-.79300	-.79300	-.79300	-.79300	-.79300	-.79300	-.79300
CXAD=	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	-.00400	-.00800	.00000	.00000	.00000	.00000	.00000	.00000
CZAD=	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	-.04000	-.08000	.00000	.00000	.00000	.00000
CMU=	-.00035	-.00035	-.00035	.00035	.00035	.00035	.00035	.00035	.00035	.00035	.00035	.00035	.00035	.00035	.00070	.00035	.00035	.00035
CMA=	.04270	.00000	-.04270	-.04270	-.04270	-.04270	-.04270	-.04270	-.04270	-.04270	-.04270	-.04270	-.04270	-.04270	-.04270	-.08270	-.04270	-.04270
CMAD=	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00088	-.00176	-.00088
CMTD=	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.0654	-.1308
CXTC=	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610	-.1610
CZTC=	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400	-3.1400
CMTC=	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100	.1100
CXB1=	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530	.3530
CZB1=	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930	.7930
CMB1=	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680	.1680
CMI =	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144	-.0144
FM =	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
GV =	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CSD =	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CS1 =	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
CS2 =	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P=	35.00	4.80	7.00	7.60	7.60	7.60	7.63	7.40	7.63	6.10	7.60	7.70	7.80	8.10	8.30	4.60	7.80	.00
T1/2=	7.10	1.30	.50	.50	.50	.50	.53	.50	.50	.40	.50	.53	.50	.50	.50	.50	.50	.19
T1/2=	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.66
T2=	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.38
T2=	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.39
P=	.00	.00	.00	20.70	20.70	20.80	20.30	20.90	20.40	18.40	20.70	20.60	20.50	20.40	16.20	25.10	20.70	25.70
T1/2=	.00	.00	.00	.00	21.20	.00	82.60	.00	.00	.00	.00	.00	.00	.00	.00	.50	.00	.00
T1/2=	.25	4.80	11.50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
T2=	2.83	5.70	8.70	81.30	.00	24.00	.00	41.90	73.10	22.30	82.20	83.10	77.70	74.70	649.00	.00	.00	.00
T2=	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

TABLE F.2A EFFECTS OF CHANGES OF LONGITUDINAL DERIVATIVES HOVER

V=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CXU=	-0.420E-05	-0.420E-05	-0.840E-05	-0.420E-05	-0.420E-05	-0.420E-05	-0.420E-05	-0.420E-05	-0.420E-05	-0.420E-05
CXW=	0.790E-05	0.790E-05	0.790E-05	-0.790E-05	0.159E-04	0.790E-05	0.790E-05	0.790E-05	0.790E-05	0.790E-05
CZU=	-0.900E-05	-0.900E-05	-0.900E-05	-0.900E-05	-0.900E-05	-0.180E-05	-0.900E-05	-0.900E-05	-0.900E-05	-0.900E-05
CZW=	-0.430E-04	-0.430E-04	-0.430E-04	-0.430E-04	-0.430E-04	-0.430E-04	-0.860E-04	-0.430E-04	-0.430E-04	-0.430E-04
CZWD=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	-0.830E-07	0.160E-06	0.000E 00
CZTD=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	-0.800E-06
CMU=	0.780E-07	0.780E-07	0.780E-07	0.780E-07	0.780E-07	0.780E-07	0.780E-07	0.780E-07	0.780E-07	0.780E-07
CMW=	0.800E-08	-0.800E-08	0.800E-08	0.800E-08	0.800E-08	0.800E-08	0.800E-08	0.800E-08	0.800E-08	0.800E-08
CMWD=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CMTD=	0.220E-06	0.220E-06	0.220E-06	0.220E-06	0.220E-06	0.220E-06	0.220E-06	0.220E-06	0.220E-06	0.220E-06
CXTC=	0.720E-02	0.720E-02	0.720E-02	0.720E-02	0.720E-02	0.720E-02	0.720E-02	0.720E-02	0.720E-02	0.720E-02
CZTC=	-0.410E-01	-0.410E-01	-0.410E-01	-0.410E-01	-0.410E-01	-0.410E-01	-0.410E-01	-0.410E-01	-0.410E-01	-0.410E-01
CMTC=	0.336E-05	0.336E-05	0.336E-05	0.336E-05	0.336E-05	0.336E-05	0.336E-05	0.336E-05	0.336E-05	0.336E-05
CXB1=	0.450E-02	0.450E-02	0.450E-02	0.450E-02	0.450E-02	0.450E-02	0.450E-02	0.450E-02	0.450E-02	0.450E-02
CZB1=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CMB1=	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02
CMI=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
P=	42.700	42.400	43.000	43.000	42.400	42.800	42.700	42.700	42.700	42.700
T1/2=	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
T1/2=	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
T2=	9.100	8.900	10.000	8.700	9.400	9.000	9.100	9.100	9.100	9.100
T2=	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
P=	1207.000	279.000	407.000	.000	267.000	.000	1173.000	1161.000	1208.000	1209.000
T1/2=	3.500	3.500	3.400	4.200	3.500	3.900	3.500	3.500	3.500	3.500
T1/2=	.000	.000	.000	2.900	.000	1.600	.000	.000	.000	.000
T2=	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
T2=	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

V=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CXU=	-0.420E-05	-0.420E-05	-0.420E-05	-0.420E-05	-0.420E-05
CXW=	0.790E-05	0.790E-05	0.790E-05	0.790E-05	0.790E-05
CZU=	-0.900E-05	-0.900E-05	-0.900E-05	-0.900E-05	-0.900E-05
CZW=	-0.430E-04	-0.430E-04	-0.430E-04	-0.430E-04	-0.430E-04
CZWD=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CZTD=	-0.160E-05	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CMU=	0.780E-07	0.158E-06	0.780E-07	0.780E-07	0.780E-07
CMW=	0.800E-08	0.800E-08	-0.800E-08	0.158E-07	0.800E-08
CMWD=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	-0.400E-09
CMTD=	0.220E-06	0.220E-06	0.220E-06	0.220E-06	0.220E-06
CXTC=	0.720E-02	0.720E-02	0.720E-02	0.720E-02	0.720E-02
CZTC=	-0.410E-01	-0.410E-01	-0.410E-01	-0.410E-01	-0.410E-01
CMTC=	0.336E-05	0.336E-05	0.336E-05	0.336E-05	0.336E-05
CXB1=	0.450E-02	0.450E-02	0.450E-02	0.450E-02	0.450E-02
CZB1=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CMB1=	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02
CMI=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
P=	33.700	42.600	42.800	42.700	42.700
T1/2=	.000	.000	.000	.000	.000
T1/2=	.000	.000	.000	.000	.000
T2=	7.300	9.100	9.200	9.000	9.000
T2=	.000	.000	.000	.000	.000
P=	279.000	279.000	.000	1265.000	1331.000
T1/2=	3.100	3.500	3.300	3.500	3.500
T1/2=	.000	.000	3.800	.000	.000
T2=	.000	.000	.000	.000	.000
T2=	.000	.000	.000	.000	.000

PM=.000196, V=0, CL=.0062, TI=.00058

TABLE F.3

EFFECT OF AUTOSAS ON LONGITUDINAL STABILITY

V=100

FM=	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	2.0	4.0	10.0	0.0	CXU= 0.48600E-02
GV=	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.0	CXA= -0.52070E 00
C50=	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.0	1.0	1.0	1.0	0.0	CZU= -0.17300E-03
C51=	0.0	0.0	0.0	0.0	0.5	1.0	0.0	0.0	2.0	2.0	2.0	2.0	0.0	CZA= -0.79300E 00
C52=	0.0	0.5	1.0	1.5	0.0	0.0	0.0	0.0	4.0	4.0	4.0	4.0	0.0	CZAD= 0.00000E 00

P=	0.0	5.0	3.0	2.3	23.2	24.7	21.3	25.3	6.2	4.9	4.8	4.7	0.0	CZTD= 0.00000E 00
T1/2=	80.0	0.7	0.7	0.7	0.0	0.0	0.0	0.0	1.2	1.4	1.4	1.4	0.0	CMU = 0.35000E-03
T1/2=	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMA = 0.00000E 00
T2=	0.0	0.0	0.0	0.0	3.7	77.5	0.1	6.1	0.0	0.0	0.0	0.0	0.0	CMAD=-0.88000E-03
T2=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0	CMTD=-0.65400E-01
P=	15.0	0.0	0.0	0.0	0.0	0.0	191.0	0.0	0.0	0.0	0.0	0.0	0.0	CXTC=-0.16100E 00
T1/2=	0.0	4.5	9.5	13.7	0.1	0.1	0.1	1.8	9.2	43.6	57.8	71.8	0.0	CZTC=-0.31400E 01
T1/2=	0.0	1.1	1.1	1.1	1.1	1.1	0.0	1.1	1.1	1.1	1.1	1.1	0.0	CMTC= 0.11000E 00
T2=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CYB1= 0.35300E 00
T2=	10.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CZB1= 0.79300E 00
														CMB1=-0.16800E 00
														CMI= -0.14400E-01

V=0

FM=	0.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	0.5	1.0	2.0	4.0	10.0	CXU= -0.42000E-05
GV=	0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	CXA= 0.79000E-05
C50=	0.0	1.0	0.0	0.0	0.0	1.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0	CZU= -0.90000E-05
C51=	0.0	1.0	0.0	0.0	1.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	CZA= -0.43000E-04
C52=	0.0	1.0	1.0	2.0	0.0	0.0	0.0	4.0	4.0	4.0	4.0	4.0	4.0	CZAD= 0.00000E 00

P=	42.7	10.2	0.0	0.0	0.0	0.0	0.0	6.2	5.4	5.1	4.9	4.8	4.8	CZTD= 0.00000E 00
T1/2=	0.0	3.3	15.6	20.3	3.2	6.5	7.7	0.2	1.9	1.6	1.5	1.4	1.4	CMU = 0.78000E-07
T1/2=	0.0	0.0	2.3	3.0	0.2	0.3	3.2	0.0	0.0	0.0	0.0	0.0	0.0	CMA = 0.80000E-08
T2=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMAD= 0.00000E 00
T2=	9.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CMTD= 0.43000E-06
P=	747.0	0.0	3.9	2.8	152.0	78.5	56.7	0.0	0.0	0.0	0.0	0.0	0.0	CXTC= 0.72000E-02
T1/2=	3.5	15.6	269.0	227.0	4.3	0.0	0.0	19.6	20.2	20.5	20.7	20.7	20.8	CZTC=-0.41000E-01
T1/2=	0.0	3.3	0.0	0.0	0.0	0.0	0.0	3.3	3.3	3.1	3.1	3.1	3.1	CMTC= 0.33600E-05
T2=	0.0	0.0	0.0	0.0	0.0	18.3	24.5	0.0	0.0	0.0	0.0	0.0	0.0	CYB1= 0.45300E-02
T2=	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	CZB1= 0.00000E 00
														CMB1=-0.13000E-02
														CMI= 0.00000E 00

TABLE F.4

EFFECT OF LATERAL DERIVATIVES AND AUTOSAS

V=100

V=	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CYV=	-.00940	-.00180	-.00940	-.00940	-.00940	-.00940	-.00940	-.00940	-.00940	-.00940	-.00940	-.00940	-.00940	-.00940	-.00940	-.00940
CLV=	.00007	.00007	-.00040	.00007	.00007	.00007	.00007	.00007	.00007	.00007	.00007	.00007	.00007	.00007	.00007	.00007
CNV=	.00040	.00040	.00040	-.00080	.00040	.00040	.00040	.00040	.00040	.00040	.00040	.00040	.00040	.00040	.00040	.00040
CYSR=	-.00110	-.00110	-.00110	-.00110	-.02200	-.00110	-.00110	-.00110	-.00110	-.00110	-.00110	-.00110	-.00110	-.00110	-.00110	-.00110
CLSD=	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
CNSD=	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300	-.19300
CYPHD=	.00000	.00000	.00000	.00000	.00000	-.00018	-.00085	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000	.00000
CLPHD=	-.00009	-.00009	-.00009	-.00009	-.00009	-.00009	-.00004	-.00009	-.00009	-.00009	-.00009	-.00009	-.00009	-.00009	-.00009	-.00009
CNPHD=	.00002	.00002	.00002	.00002	.00002	.00002	.00002	.00002	.00002	.00002	.00002	.00002	.00002	.00002	.00002	.00002
CYDS=	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500	-.40500
CLDS=	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600	-.11600
CNDS=	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010	-.02010
CYDR=	.11400	.11400	.11400	.11400	.11400	.11400	.11400	.11400	.11400	.11400	.11400	.11400	.11400	.11400	.11400	.11400
CLDR=	.02500	.02500	.02500	.02500	.02500	.02500	.02500	.02500	.02500	.02500	.02500	.02500	.02500	.02500	.02500	.02500
CNDR=	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400	-.11400
FK=	.0	.0	.0	.0	.0	.0	.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	.3	1.0
CV=	.0	.0	.0	.0	.0	.0	.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CEC=	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5	1.0	1.0	1.0	1.0
CE1=	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.5	1.0	.0	.0	2.0	1.0
CE2=	.0	.0	.0	.0	.0	.0	.0	.5	1.0	1.5	.0	.0	.0	.0	4.0	1.0
P=	10.6	10.7	8.4	10.8	10.5	10.6	10.6	7.2	1.5	1.3	62.5	.0	2.4	30.9	3.9	3.7
T1/2=	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	3.9	2.4	.0	.0	.9	.7
T1/2=	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	9.5	.0	.0	.0
T2=	2.7	2.9	2.0	3.5	2.4	2.1	2.7	16.9	26.4	36.3	.0	.0	9.3	14.4	.0	.0
T2=	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
P=	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
T1/2=	.1	.8	.7	.7	.9	.8	.8	1.7	1.8	1.8	.1	.1	1.3	1.5	1.8	1.8
T1/2=	.5	.1	.1	.1	.5	.1	.1	.1	.1	.1	.1	.0	.1	.1	2.6	1.8
T2=	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
T2=	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

TABLE F.4A

EFFECT OF CHANGES OF LATERAL DERIVATIVES AND AUTOSAS HOVER

CYV=	-0.610E-04	0.120E-03	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04
CLV=	-0.760E-06	-0.760E-06	-0.600E 01	-0.760E-06	-0.760E-06	-0.760E-06	-0.760E-06	-0.760E-06
CNV=	0.520E-05	0.520E-05	0.520E-05	0.100E-04	0.520E-05	0.520E-05	0.520E-05	0.520E-05
CYSD=	0.148E-03	0.148E-03	0.148E-03	0.148E-03	0.240E-03	0.148E-03	0.148E-03	0.148E-03
CLSD=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CNSD=	-0.148E-03	-0.148E-03	-0.148E-03	-0.148E-03	-0.148E-03	-0.300E-03	-0.148E-03	-0.148E-03
CYPHF=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CLPHF=	0.180E-05	0.180E-05	0.180E-05	0.180E-05	0.180E-05	0.190E-05	0.360E-05	0.130E-05
CNPHF=	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.600E-06
CYDS=	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02
CLDS=	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02
CNDS=	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03
CLDR=	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02
CNDR=	0.400E-03	0.400E-03	0.400E-03	0.400E-03	0.400E-03	0.400E-03	0.400F-03	0.400E-03
CNDR=	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02
P=	12.30	13.80	9.70	12.20	12.20	12.30	12.30	12.20
T1/2=	.00	.00	.00	.00	.00	.00	.00	.00
T1/2=	.00	.00	.00	.00	.00	.00	.00	.00
T2=	3.20	1.28	2.40	3.30	3.20	3.20	3.20	3.20
T2=	.00	.00	.00	.00	.00	.00	.00	.00
P=	.00	.00	.00	.00	.00	86.90	.00	.00
T1/2=	1.56	1.50	.00	1.70	1.70	.97	2.00	2.00
T1/2=	1.00	1.40	.00	1.00	1.00	.00	1.00	1.00
T2=	.00	.00	.00	.00	.00	.00	.00	.00
T2=	.00	.00	.00	.00	.00	.00	.00	.00

CYV=	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04	-0.610E-04
CLV=	-0.760E-06	-0.760E-06	-0.760E-06	-0.760E-06	-0.760E-06	-0.760E-06	-0.760E-06	-0.760E-06	-0.760E-06	-0.760E-06
CNV=	0.520E-05	0.520E-05	0.520E-05	0.520E-05	0.520E-05	0.520E-05	0.520E-05	0.520E-05	0.520E-05	0.520E-05
CYSD=	0.148E-03	0.148E-03	0.148E-03	0.148E-03	0.148E-03	0.148E-03	0.148E-03	0.148E-03	0.148E-03	0.146E-03
CLSD=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CNSD=	-0.148E-03	-0.148E-03	-0.148E-03	-0.148E-03	-0.148E-03	-0.148E-03	-0.148E-03	-0.148E-03	-0.148E-03	-0.148E-03
CYPHF=	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CLPHF=	0.180E-05	0.180E-05	0.180E-05	0.180E-05	0.180E-05	0.180E-05	0.180E-05	0.180E-05	0.180E-05	0.180E-05
CNPHF=	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.310E-06	0.310E-06
CYDS=	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02	-0.450E-02
CLDS=	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02	-0.130E-02
CNDS=	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03	-0.230E-03
CLDR=	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180F-02	0.180E-02	0.180E-02	0.180E-02
CNDR=	0.400E-03	0.400E-03	0.400E-03	0.400E-03	0.400E-03	0.400E-03	0.400E-03	0.400E-03	0.400E-03	0.400E-03
CNDR=	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02	0.180E-02
FM=	1.00	1.00	1.00	1.00	1.00	.25	.25	1.00	4.00	10.00
CV=	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CG0=	.00	.00	.00	.00	.50	1.00	1.00	1.00	1.00	1.00
CG1=	.00	.00	.50	1.00	.00	.00	2.00	2.00	2.00	2.00
CG2=	1.00	1.50	.00	.00	.00	.00	4.00	4.00	4.00	4.00
P=	1.75	1.54	1.40	1.24	1.70	1.20	1.30	1.20	1.20	1.10
T1/2=	.00	.00	.00	.00	2.10	2.10	29.40	3.00	3.40	2.20
T1/2=	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
T2=	.29	.27	.70	1.00	.00	.00	.00	.00	.00	.00
T2=	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
P=	1.80	1.60	.00	.00	306.00	433.00	3.80	3.60	3.60	3.60
T1/2=	.25	.24	1643.00	3285.00	1147.00	2294.00	.70	.70	.70	.70
T1/2=	.00	.00	.08	.05	.09	.00	.00	.00	.00	.00
T2=	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
T2=	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

TABLE F.5

EXAMPLE III - SUMMARY OF STATIC STABILITY

PITCH TRIM AND SIDESLIP

V_{KTS}	V'/sec	x	h	δ_s	n	PITCH TRIM B_1 (1)	θ_c	SIDESLIP $\frac{d\phi}{d\beta}$	$\frac{d\theta_{TR}}{d\phi}$	$\frac{dA_1}{d\phi}$	$\frac{d\theta_{TR}}{d\beta}$	$\frac{dA_1}{d\beta}$
	0	.5	6.25	087	1	4.6	14.9					
100	169					5.1/9.3	7.42	-.031	-64.2	3.0	1.98	-.093
125	212					/11.1	8.4	-.31	-11.4	.46	3.54	-.143
150	254					5.5/13/6	9.4	-.61	-9.2	.34	5.6	-.207
	0	0				0	15					
100	169					3.2/5.8	7.4	-.031	-64.2	3.0	1.98	-.093
125	212					3.7/7.9	8.4	-.31	-11.4	.46	3.54	-.143
150	254					4.5/10.85	9.4	-.61	-9.2	.34	5.6	-.207
	0	-1				-9.2	14.9					
100	169					-7.8/-1.4	7.4	-.031	-64.2	3.0	1.98	-.093
125	212					.75/1.6	8.4	-.31	-11.4	.46	3.54	-.143
150	254					2.2/5.2	9.4	-.61	-9.2	.34	5.6	-.207

(1) $\frac{d1t}{dB_1} = 1$

TABLE F.5

EXAMPLE III - SUMMARY OF STATIC STABILITY (cont'd)

PITCH TRIM AND SIDESLIP

						PITCH TRIM		SIDESLIP				
V_{KTS}	V'/sec	x	h	δ_s	n	(1) B_1	θ_c	$\frac{d\phi}{d\beta}$	$\frac{d\theta_{TR}}{d\phi}$	$\frac{dA_1}{d\phi}$	$\frac{d\theta_{TR}}{d\beta}$	$\frac{dA_1}{d\beta}$
		0	6.25	.087	1	3.1/5.7	7.4					
100	169				1.5	3.0/5.5	7.4					
125	212				2.0	2.9/5.25	7.4					
150	254				2.5	2.74/5.0	7.4					
0					1	3.7/8.0	8.4					
100					1.5	3.6/7.8	8.4					
125					2.0	3.5/7.6	8.4					
150					2.5	3.4/7.45	8.4					
0	0		5.25		1	0	15.0					
100	169		5.25			3.0/5.8	7.4	-.031	-64.2	3.0	1.98	-.093
125	212		5.25			3.4/5.8	8.4	0.30	-11.4	.46	3.54	-.143
150	254		5.25			4 0/7.9	9.4	-.61	-9.2	.34	5.6	-.207
0	0		6.25	.174		0	14.9					
100	169					/5.7	7.4	-.031	-64.3	3.0	1.98	-.093
125	212					3.7/8.0	8.4	-.31	-11.4	.46	3.54	-.143
150	254					4.4/10.9	9.2	-.61	-9.2	.34	5.6	-.207

TABLE F.5

EXAMPLE III - STATIC STABILITY (Continued)

STEADY TURNS

V = 100 KTS

FWD C.G.

BANK ANGLE	CLIMB ANGLE	LOAD FACTOR	θ_{tR} TAIL ROTOR COLLECTIVE	A_1 LATERAL CYCLIC	B_1 PITCH CYCLIC
0	-15				
	0	1		0	-1.8
	15				
10	-15	1.02	.43	0	.29
	0	1.02	.43	0	.29
	15	1.02	.43	0	.29
20	-15	1.06	.85	-.01	1.18
	0	1.06	.85	0	1.18
	15	1.06	.85	.01	1.18
30	-15	1.15	1.24	-.02	2.73
	0	1.15	1.24	0	2.73
	15	1.15	1.25	.02	2.73
40	-15	1.31	1.59	-.02	5.05
	0	1.31	1.60	0	5.05
	15	1.31	1.61	.02	5.05
[illegible]0	-15	1.56	1.89	-.03	8.45
	0	1.56	1.90	0	8.45
	15	1.56	1.92	.03	8.45

TABLE F.6

LONGITUDINAL DERIVATIVES

	1	2	3	4	5	6	7
CXU	-0.250E-05	-0.110E-05	-0.110E-05	-0.110E-05	-0.140E-05	-0.110E-03	-0.470E-03
CZU	0.210E-05	-0.440E-05	-0.440E-05	-0.440E-05	-0.510E-05	-0.310E-05	-0.610E-05
CMU	0.600E-06	0.610E-06	0.600E-06	0.600E-06	0.770E-06	0.960E-06	0.200E-05
CXA	0.550E-05	0.420E-05	0.420E-05	0.430E-05	0.490E-05	0.620E-05	0.140E-02
CZA	-0.400E-04	-0.830E-04	-0.830E-04	-0.830E-04	-0.950E-04	-0.430E-02	-0.350E-01
CMA	0.000E 00	-0.230E-05	-0.230E-05	-0.230E-05	-0.260E-05	0.880E-04	-0.810E-02
CXAD	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CZAD	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CMAD	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CXTD	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CZTD	0.000E 00	-0.100E-06	-0.100E-06	-0.100E-06	-0.110E-06	-0.620E-04	-0.240E-03
CMTD	-0.170E-05	-0.940E-05	-0.940E-05	0.670E-03	0.140E-03	0.900E-04	-0.320E-03
CXB	0.380E-02	0.110E-02	0.110E-02	-0.470E-07	0.290E-02	0.170E-02	0.180E-02
CZB	0.000E 00	0.370E-03	0.370E-03	0.370E-03	0.250E-03	0.110E-02	0.150E-02
CMB	-0.530E-02	-0.320E-03	-0.310E-03	-0.220E-01	-0.650E-02	-0.460E-03	-0.470E-03

LATERAL DERIVATIVES

	1	2	3	4	5	6	7
CYV	-0.610E-06	-0.180E-05	-0.180E-05	-0.190E-05	-0.220E-05	-0.430E-03	-0.370E-02
CLV	-0.600E-06	-0.490E-05	-0.490E-05	-0.480E-06	-0.570E-06	-0.640E-04	-0.550E-03
CNV	0.500E-05	0.650E-06	0.650E-06	0.650E-06	0.650E-06	0.490E-03	0.520E-02
CYSC	0.100E-03	0.140E-04	0.140E-04	0.140E-04	0.140E-04	0.150E-03	0.350E-03
CLSC	0.000E 00	0.330E-05	0.330E-05	0.330E-05	0.330E-05	0.270E-04	0.620E-04
CNSC	-0.130E-03	-0.180E-04	-0.180E-04	-0.180E-04	-0.180E-04	-0.180E-03	-0.430E-03
CYTC	0.000E 00	-0.370E-04	-0.370E-04	-0.270E-05	-0.880E-04	-0.730E-04	-0.680E-04
CLTC	0.270E-04	-0.100E-04	-0.100E-04	-0.670E-03	-0.190E-03	-0.220E-04	-0.140E-04
CNTC	-0.200E-03	0.320E-05	0.320E-05	0.330E-05	0.330E-05	0.290E-04	0.630E-04
CYA	0.370E-02	0.110E-02	0.110E-02	0.500E-07	0.290E-02	0.180E-02	0.210E-02
CLA	0.100E-02	0.240E-02	0.240E-03	0.230E-01	0.650E-02	0.710E-03	0.120E-02
CNA	-0.540E-04	0.260E-04	0.000E 00	0.000E 00	0.000E 00	0.000E 00	0.000E 00
CYDR	0.240E-02	0.580E-03	0.580E-03	0.580E-03	0.580E-03	0.200E-02	0.400E-02
CLDR	0.550E-03	0.130E-03	0.130E-03	0.130E-03	0.130E-03	0.460E-03	0.910E-03
CNDR	-0.300E-04	-0.720E-03	-0.720E-03	-0.720E-03	-0.720E-03	-0.250E-02	-0.490E-02

1 TABLE A1 V= 0
2 TABLE A2 TEETER HR=-.5 V= 0
3 TABLE A2 TEETER HR=0.0 V= 0
4 TABLE A2 RIGID HR=0.0 V= 0
5 TABLE A2 ARTIC HR=0.0 V= 0
6 TABLE A2 ARTIC HR=0.0 V= 40
7 TABLE A2 ARTIC HR=0.0 V=140

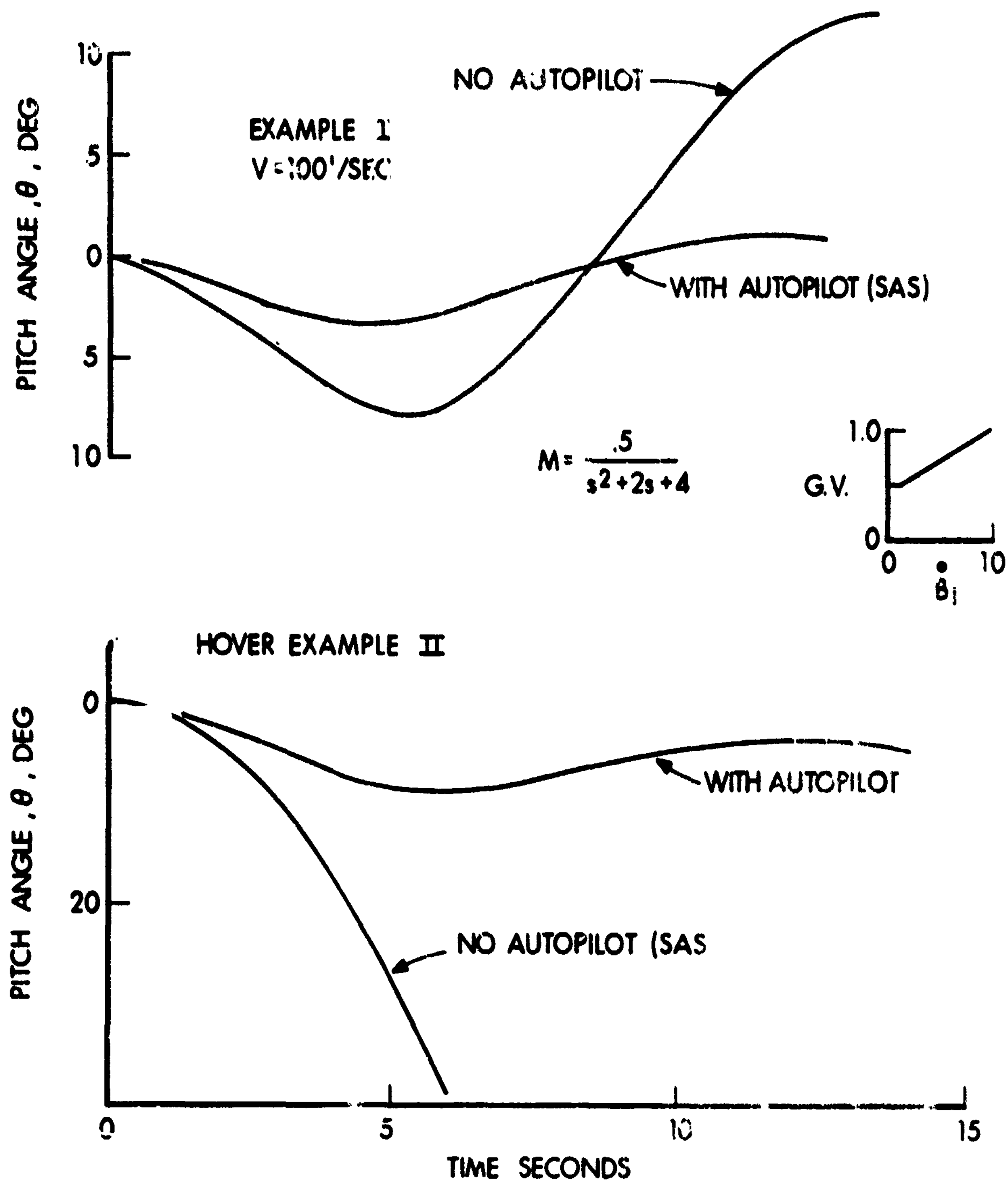


Figure F-1. Effect of Autopilot Dynamics Longitudinal Stability 1° Longitudinal Cyclic Pulse.

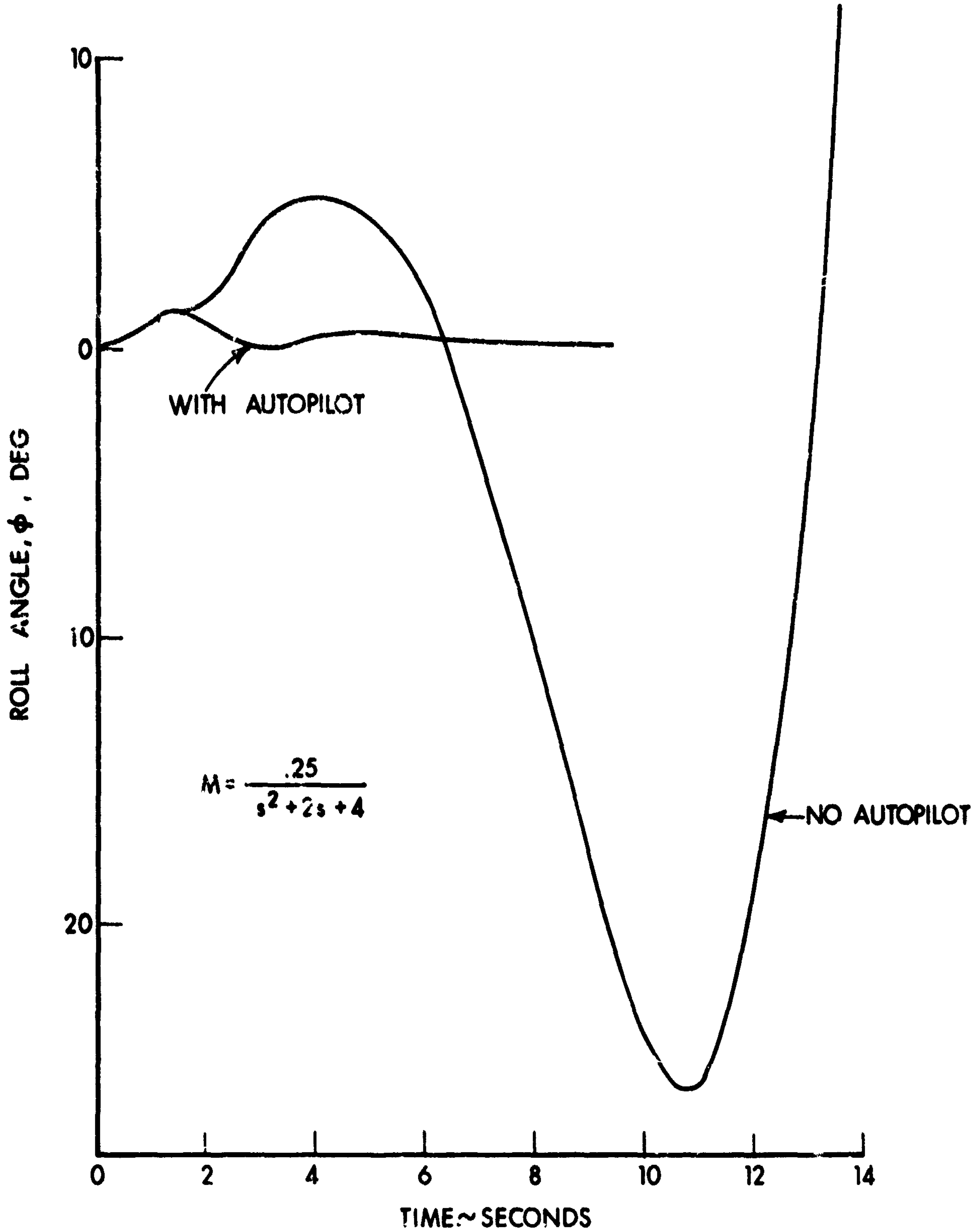


Figure F-2. Effect of Autopilot Dynamic Lateral Stability Hover 1° Lateral Cyclic Pulse Example II.

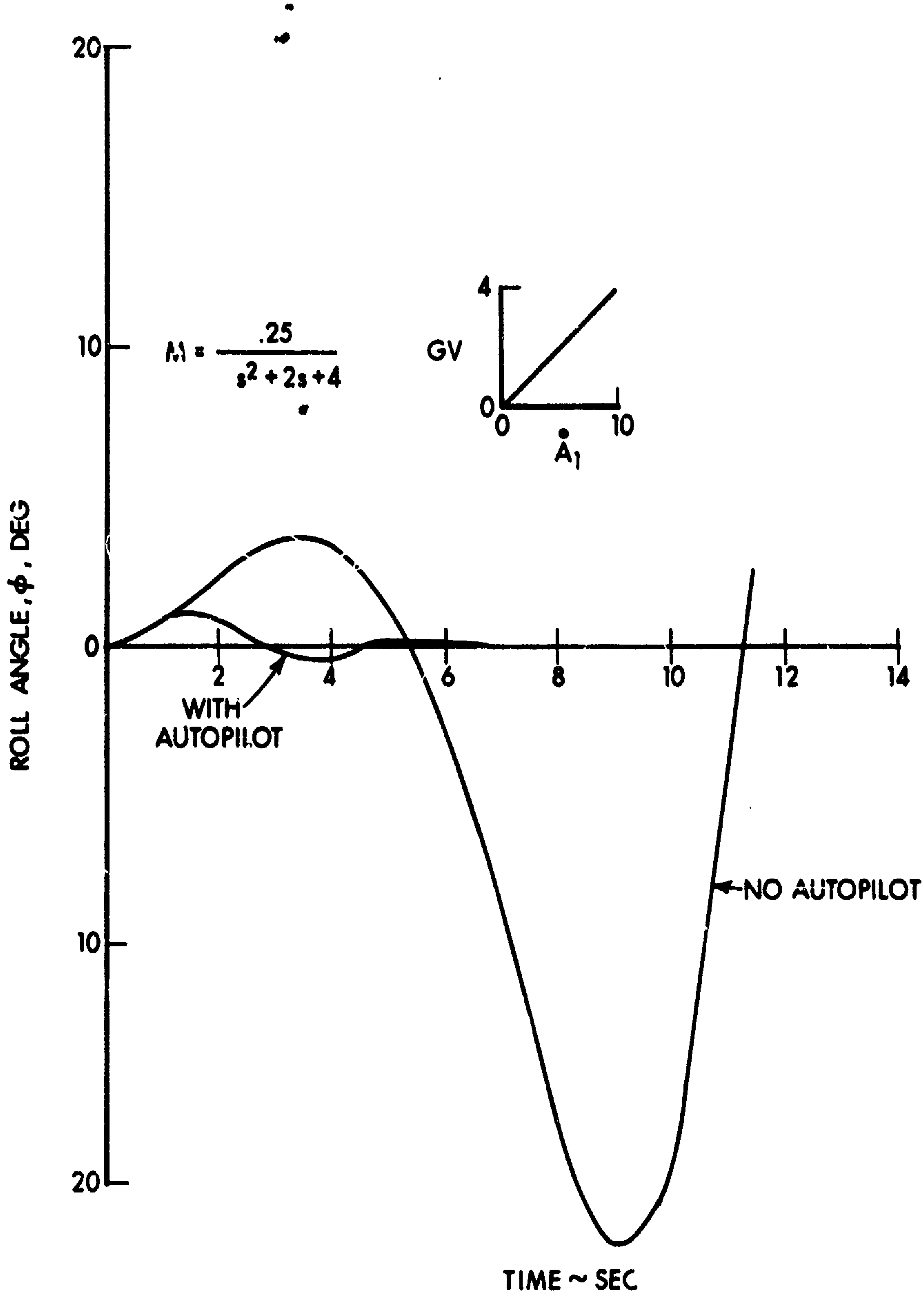


Figure F-3. Effect of Autopilot Dynamic Lateral Stability Velocity = 100'/sec 1° Lateral Cyclic Pulse Example I.

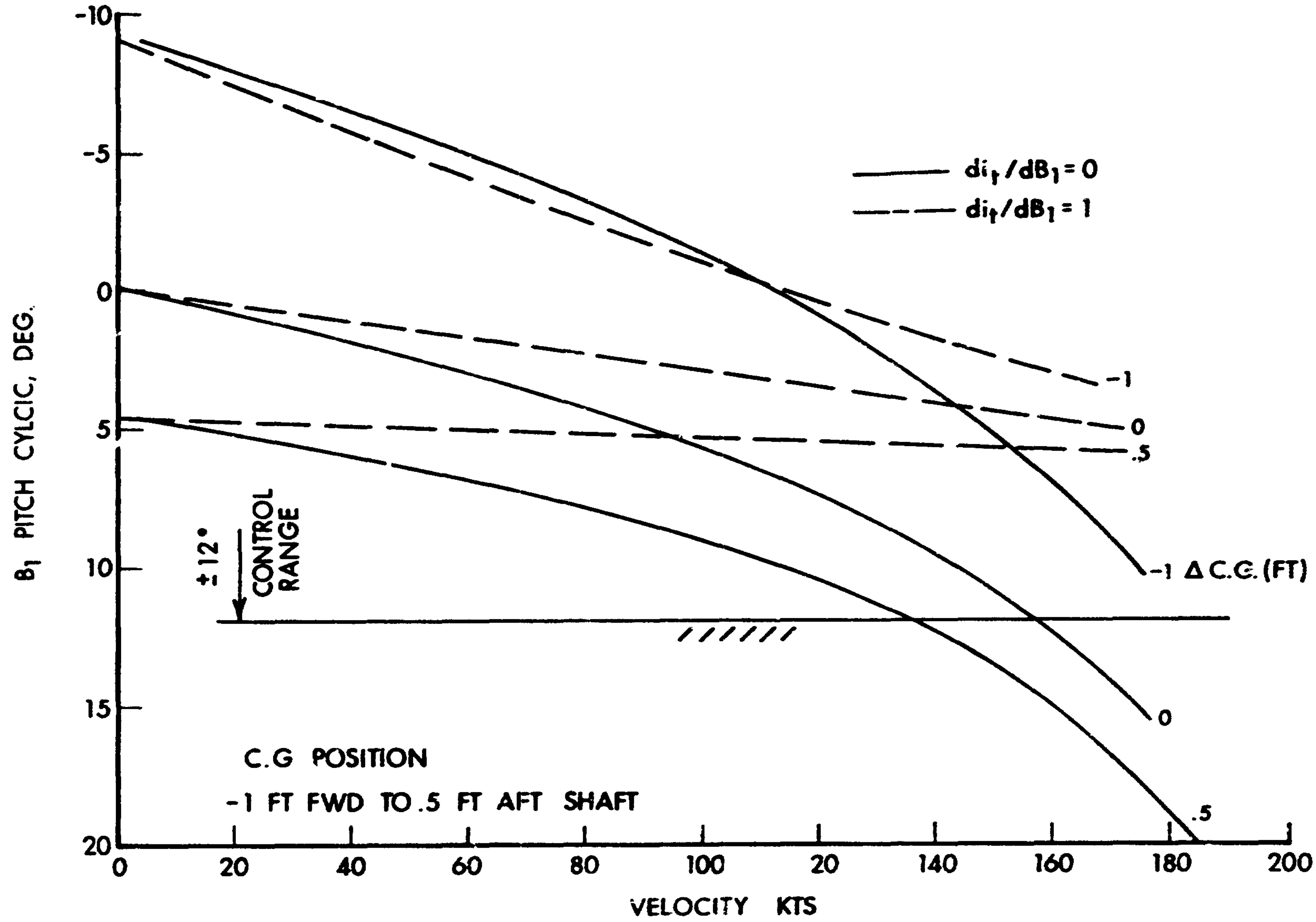


Figure F-4. Example III Level Flight Trim B vs V Effect of Horizontal Tail Coupling.

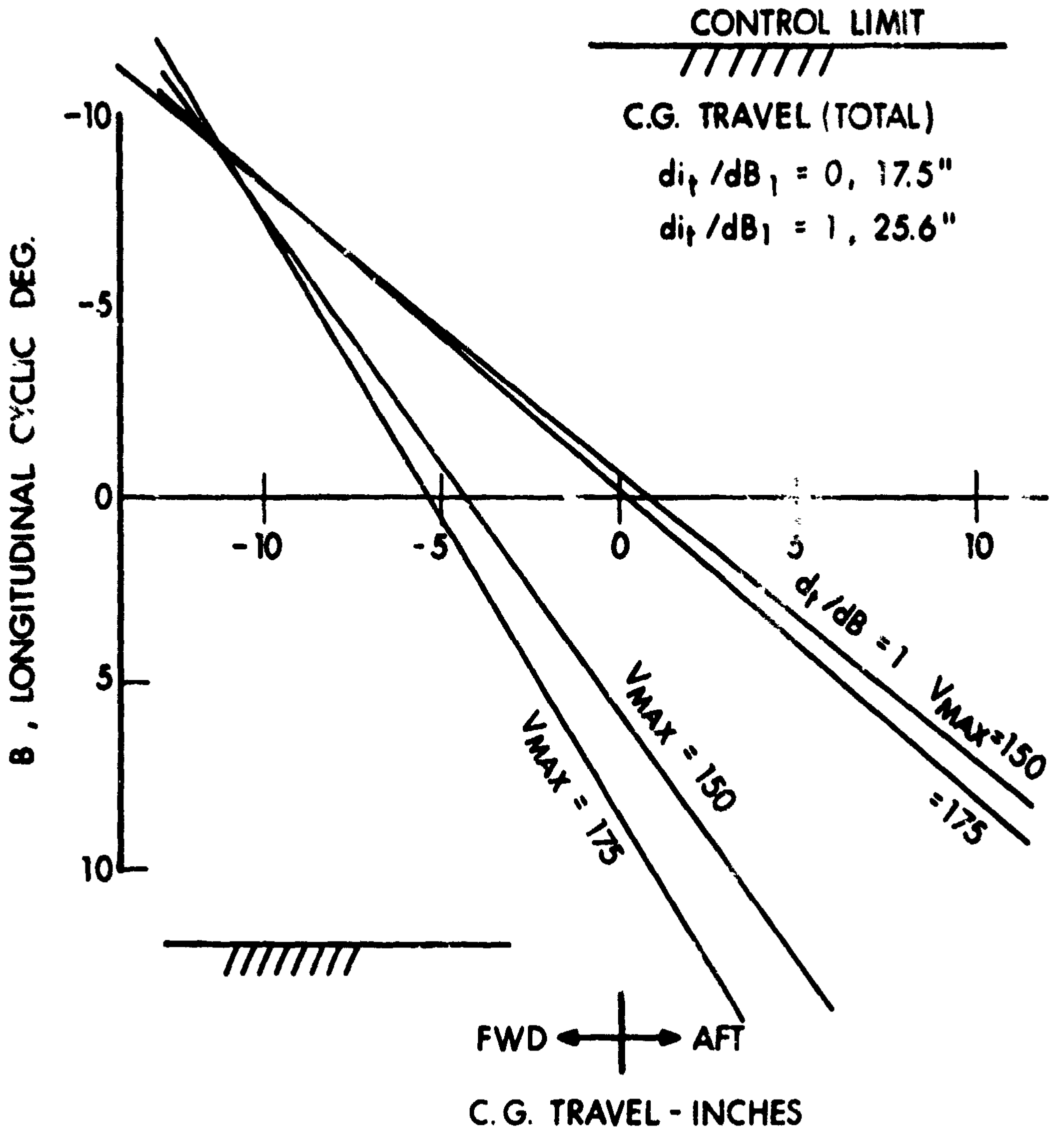


Figure F-5. Example III Estimated C.G. Travel for ±12° Longitudinal Cyclic Control Power Trim Limits Between Hover (Fwd C.G.) and High Speed.

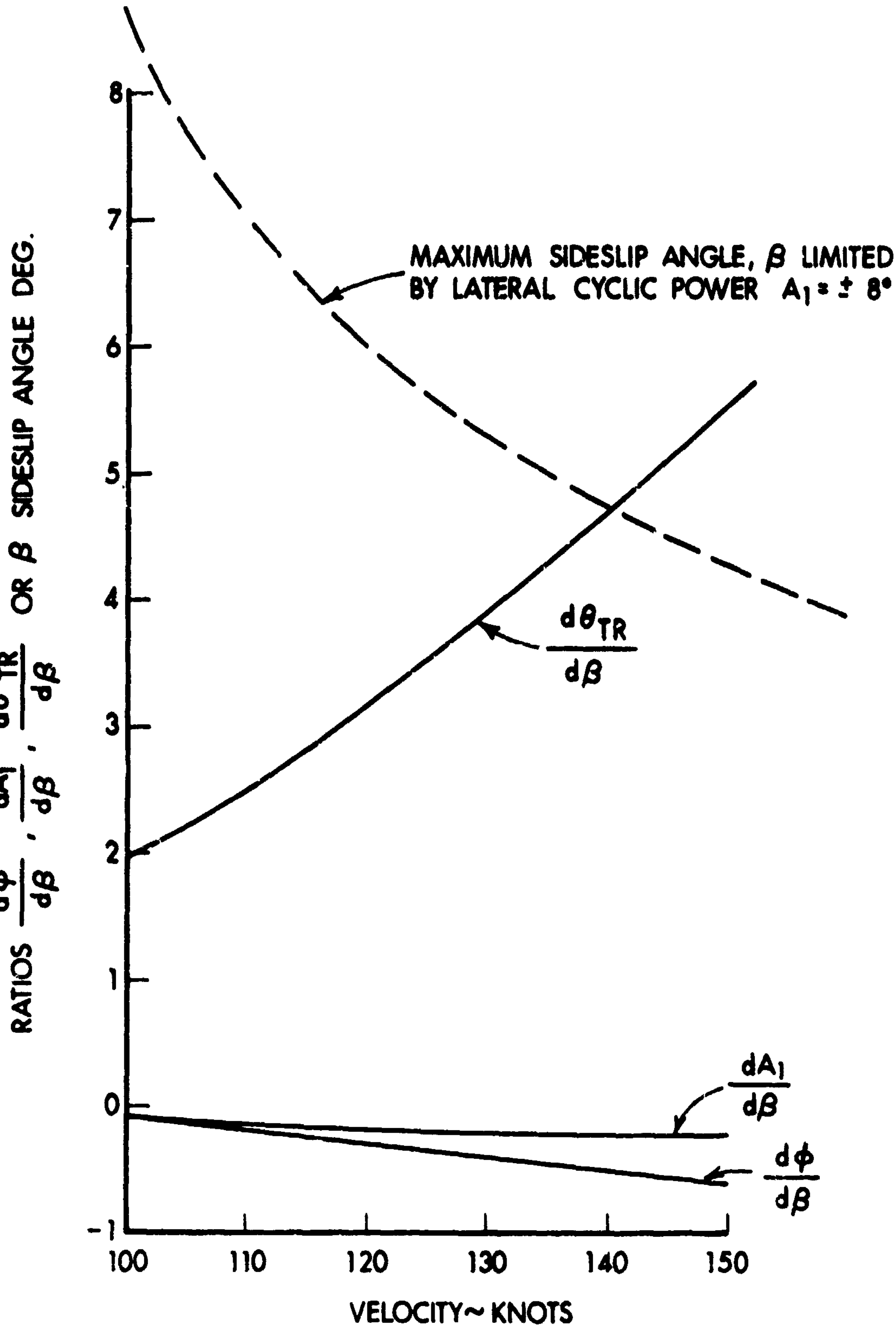


Figure F-6. Example III Steady Sideslips Level Flight Power.

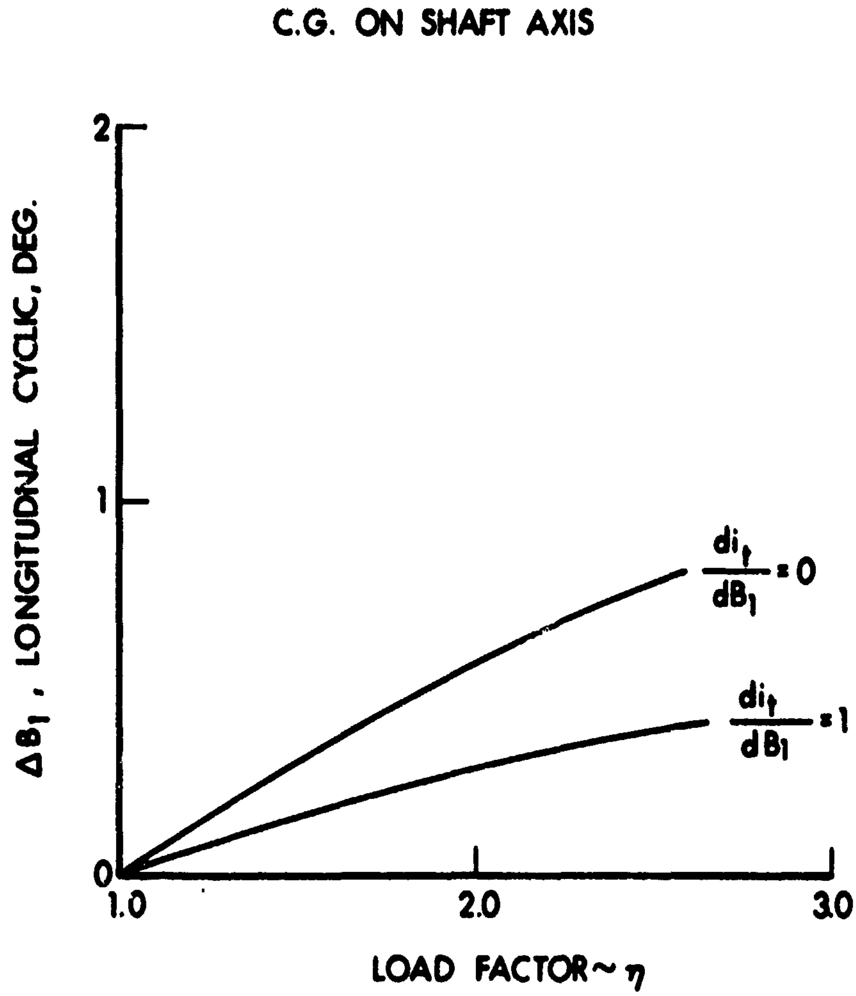


Figure F-7. Example III Pull Up Velocity 100 kts Control Position vs Load Factor.

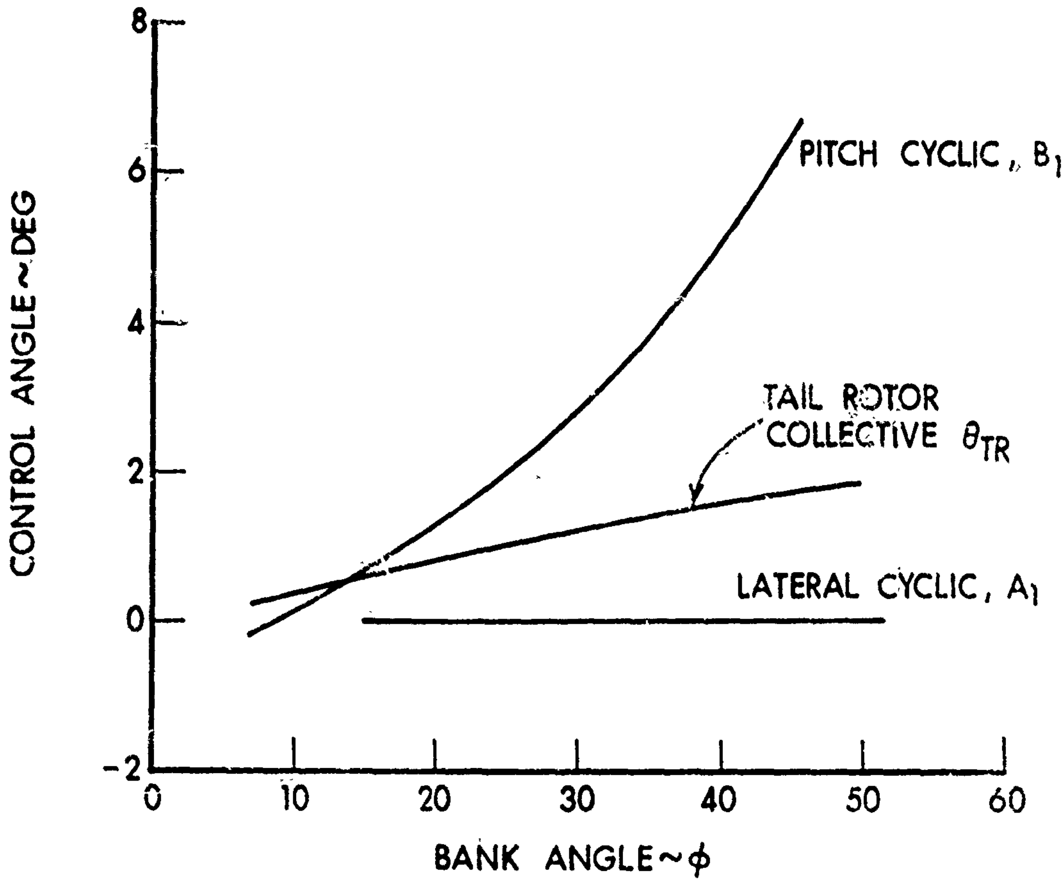


Figure F-8. Example III Control Angle vs Bank Angle
Steady Turn V= 100 kts.

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